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Heliport/Vertiport Design Deliberations 1997 - 2000

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Final Report

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16. Abstract

During the last several years, the FAA has been working toward the revision of both the Heliport Design advisory circular, AC150/5390-2B, and the Vertiport Design AC, AC150/5390-3. This work has been done in cooperation with Industry via meetings, discussions, and working papers. This report documents some of the some of the more significant issues that have been discussed during the 1997 to 2000 time period.

While heliports and vertiports are different, many of the design issues are similar. Indeed, the FAA has previously announced its intentions to combine the two advisory circulars (AC) into one AC. This is why both subjects are addressed in the same report.

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1.0 BACKGROUND

During the 1997-1999 time period, the Federal Aviation Administration developed a revision of the Heliport Design advisory circular, AC5390-2A (approved January 20, 1994). The draft revision was released for public review and comment in January 2000.

During the 1997-1999 time period, the Federal Aviation Administration, also worked with the Vertical Flight Industry to initiate a revision of the Vertiport Design advisory circular, AC5390-3 (approved May 31, 1991). At this time, it appears that it will be many months before a revised Vertiport Design AC will be available for public review and comment.

During this time period, a number of documents were written by a variety of people. This report is a collection of some of the more important documents.

2.0 INTRODUCTION

Appendix A contains the minutes of the FAA/Industry Vertiport Design Working Group meetings held during 1997-1999. Working Group meetings were held prior to 1997. In retrospect, however, it is clear that these meetings were premature. The information needed to make decision on the revision of the Vertiport Design AC was not yet available and no significant progress was made.

Appendix B contains white papers developed by members of the FAA/Industry Vertiport Design Working Group.

Appendix C contains a list of references that address various topics of interest to the members of the FAA/Industry Vertiport Design Working Group.

Appendix D contains heliport design white papers developed as a means of addressing a variety of issues.

Appendix E contains the FAA/Industry Heliport Design Consensus Statement. This is the 16th version of a document developed during the extended negotiations between the FAA and Industry. Negotiations continued for almost a year after this particular version of the Consensus Statement was written. In the interest of keeping this a relatively high-level document, a very large number of consensus items were not included in this statement. In addition, under pressure from the Air Ambulance Industry, the FAA backed off on its intentions to adopt two-slope approach/departure paths. The two-slope approach/departure paths had been agreed upon by Industry and had been included in several draft versions of the revised AC. However, the two-slope approach/departure paths were not included in the version released for public review and comment.

APPENDIX A.
FAA/INDUSTRY VERTIPORT DESIGN WORKING GROUP MINUTES

This appendix contains minutes for Working Group meetings arranged in the following order:

Working Group Minutes: August 30, 1999

Working Group Minutes: January 28, 1999

Working Group Minutes: October 14, 1998

Working Group Minutes: August 20, 1998

Working Group Minutes: June 1, 1998

Working Group Minutes: November 18, 1997

Working Group Minutes: July 22, 1997

Working Group Minutes: April 22, 1997

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
August 30, 1999

Attendance

Robert Bonanni, FAA Co-chairman
Craig Allison, Bell Helicopter
Vaughan Askue, Sikorsky
Bill Decker, NASA Ames
Lorry Faber, FAA SW Region
Guy Heneault, Transport Canada

Dr. John Leverton, Industry Co-chairman
Norm Mowbray, Bell Textron
Bill Sanderson, HAI
Robert D. Smith, FAA
Alan Todd, Bell Helicopter
Ryan Wilkins, Boeing Helicopter

Minutes

1. **Co-Chairman's Remarks and Host's Welcome.** Dr. Leverton chaired the meeting and briefly addressed today's agenda. Mr. Bonanni spoke of his expectations for today's meeting. Acting as our Bell Textron host, Mr. Mowbray welcomed the participants.

2. **Minutes of Previous Meetings.** After recent meetings, we have not managed to finalize the minutes and distribute them in an expedient manner. The co-chairmen have agreed to strive to distribute minutes to all members as soon as possible after each meeting. The FAA will distribute minutes to FAA, NASA, and Transport Canada members and to HAI. HAI will distribute minutes to the Industry members. As secretary, Mr. Smith will continue to prepare the minutes.

3. **Heliport Design AC Status.** Mr. Bonanni spoke of the ongoing discussions and expressed his hope that the draft AC would be released for public review and comment sometime in November. Dr. Leverton stated that he and Bill Sanderson were currently reviewing the draft document prior to issue.

4. **CTR Certification Basis.** Ms. Faber stated that no official changes have been made to the certification basis although changes are under discussion. These discussions are expected to finalized and formal changes made in about 12 months. Tiltrotor certification discussions with other certification authorities have taken place. At this time, JAA validation is still on-going with respect to the BA609. At the present time, the FAA has no performance data on the BA609.

5. **Vertiport Categories – Industry Discussion Paper.** At the start of the meeting, Dr. Leverton distributed an updated version [Issue 5 dated 27 August 1999] of an Industry position paper entitled Vertiport Design. An earlier version of this document (dated August 22) had been previously distributed to some of the working group members. Dr. Leverton commented that, in writing this paper, he had struggled with defining a proposed advisory structure and defining terminology. This is particularly difficult due to the US regulatory structure for operations. Unlike some other countries that have such a structure for private, general aviation, and transport, the USA does not and only two operational categories exist: Part 91 and Part 135. At one time, there had been a Part 127 for helicopter transport operations, but this Part has since been withdrawn. Although this discussion paper is based on extensive, ongoing discussions with Bell Helicopter and limited previous discussions with Boeing Helicopter, Dr. Leverton cautioned the WG that the framework in the paper is his. Bell has not been in complete agreement with it. Others also may wish to take exceptions on a number of points but it is a start and should prompt productive discussion. On this basis, he solicited comments.

Mr. Todd commented that Bell had some additional editorial comments on the discussion paper but was in general agreement with the bulk of the document.

Several WG members (Industry, FAA, and NASA) complimented Dr. Leverton for authoring the paper. It is always difficult to break new ground on such matters but the ground must be broken and a foundation proposed if we are to construct the building.

In his paper, Dr. Leverton had proposed the following categories of vertiports:

1. VTOL Private – Prior Permission Required (PPR)
2. VTOL General Aviation
3. VTOL Transport
4. STOL Private (PPR)
5. STOL General Aviation
6. STOL Transport

Mr. Bonanni responded that the FAA is not yet prepared to agree on a list of vertiport categories to be addressed in the AC. However, he was uncomfortable with the concept of private or PPR vertiports. The FAA is revising the Heliport Design AC with the specific intent of deleting the chapter on private heliports. Based on comments from Industry, the agency is considering the concept of PPR heliports. Industry strongly favors the definition of PPR heliports and a lower design standard for such facilities. Recognizing that there is a large infrastructure of existing heliports, recognizing that we have extensive operational experience with these facilities, recognizing that it will not be possible to modify all of these facilities overnight, the FAA is considering the PPR concept and other compromises to lessen the economic burden of changes to the Heliport Design AC. With vertiports, however, there is NOT a large infrastructure of existing facilities. We do NOT have extensive operational experience with these facilities or with the tiltrotor itself. While the FAA is interested in hearing the discussion on this subject, it does not seem appropriate to include in the revised Vertiport Design AC any discussion of private vertiports or PPR vertiports.

Ms. Faber questioned whether it would not be appropriate to discuss facility design requirements based on operations under Parts 91, 135, and 121. In a philosophical discussion of facility design advisory circulars and state laws, she reminded people that an AC is what the FAA WANTS people to do, not what the FAA REQUIRES them to do.

Mr. Decker cautioned the WG with regard to the comparison of the tiltrotor with STOL airplanes. While there are similarities in performance between the tiltrotor and STOL airplanes, there are great differences in control capability. In comparison with STOL airplanes, helicopters have great control down to hover because they decelerate in the process. The tiltrotor should have similar control capability. Mr. Decker also commented that he sees the need for extensive testing to demonstrate how the tiltrotor will perform and how vertiports will need to be designed. He noted to the WG that the majority of NASA's attention of tiltrotor had been focused on the large transport vehicle. The BA609 will be a different aircraft in some respects. At this point, these differences are not fully understood.

Mr. Bonanni commented that the lack of tiltrotor performance data is an issue. Also of concern to the FAA is the lack of extensive operational experience. Only time, an extensive amount of time, will provide this large body of operational experience. Industry requirements dictate that we can not afford to wait that long to publish a revision of the Vertiport Design AC. The lack of extensive operational experience will require the FAA to take a conservative perspective in revising the Vertiport Design AC. As we gain extensive operational experience, FAA's Vertiport Design recommendations will continue to evolve, but we will necessarily start with a conservative approach.

Mr. Todd stated that Bell's simulation experts had recently completed their efforts to optimize the Bell BA609 simulation model. On this basis, he is optimistic that he will be able to provide BA609 performance data necessary to guide vertiport design in about 30 days. This information will be provided to the WG.

Mr. Smith commented on the paper's proposal that a protection zone should not be required at a private vertiport. It appeared that the principal reason for including private vertiports in the proposed list might have been to provide some excuse to argue that a protection zone is not required at private vertiports. In discussions on the Heliport Design AC, Industry argued fiercely against an FAA proposed recommendation of protection zones at private heliports. Recognizing that there is a large existing infrastructure of existing heliports, the FAA has reluctantly accepted Industry's passionate arguments on issues of economic impact and risk. In a discussion of vertiport design requirements, such arguments can not be supported since there is no large infrastructure of existing vertiports. Thus, there does not appear to be any convincing argument that a protection zone is unnecessary at some vertiports.

Dr. Leverton commented that, since the tiltrotor will operate like a helicopter for the takeoff and landing, he felt it should be considered in the same manner as a helicopter.

During the discussion, Dr. Leverton called the WG's attention to an issue concerning the discussion of vertiport design parameters. He stated that he had intentionally separated recommendations for various design parameters (TLOF, FATO, RTOA, etc.). While one might choose to lump these all together, he considered it more helpful to follow the lead of Transport Canada and define them separately. Several WG members commented that it was a wise choice to define them separately at this stage. A decision can be made later as to whether they should be combined into one dimension for length.

Dr. Leverton commented that the existing Vertiport Design AC is somewhat illogical. A number of issues are not addressed at all. Other issues are not addressed in sufficient depth. This is one factor in his sense of urgency in revising the Vertiport Design AC.

WG comments on many of the details of the discussion paper were limited since most members had not had sufficient time to review it. As a result, on much of the document, there was no discussion at all. Dr. Leverton asked that all WG members take this review as homework in preparation for the next meeting.

6. <u>Ground: Aspects to be Considered</u>. In the agenda, Dr. Leverton had proposed the following ground space categories to be addressed in the AC:

TLOF (VTOL/STOL)
FATO (VTOL/STOL)
RTOA/Rollway (VTOL/STOL)
Safety Zone
Protection Zone (Rollway Protection Zone/Clearway)
LAAS Area

Dr. Leverton asked is these terms were appropriate for infrastructure for vertiport infrastructure. No WG member objected to any of these terms.

Dr. Leverton asked if there were any additional issues that need to be addressed. Mr. Bonanni commented that additional infrastructure issues to be addressed included RPZs, fire and rescue requirements, stabilized areas for fire fighting, stabilized areas for aircraft veer off. He asked the WG to recall the draft vertiport layout diagram that he had distributed at a prior meeting. To focus attention on these issues, Dr. Leverton suggested that we again distribute this diagram.

Mr. Smith call the WG's attention to the last figure in the discussion paper. This figure, entitled "Proposed Layout: Vertiport with Elongated 'TLOF' " is a product of what we have learned from NASA's tiltrotor simulation efforts. It will take some additional discussion to agree on terminology for the various features of this layout and we should strive to do so soon. It will probably take longer to agree on recommended markings for the various components of this layout but this is less pressing. Putting this proposal in writing is a very valuable first step and Dr. Leverton should be commended for doing so.

Mr. Decker cautioned the WG that, in trying to learn from the extensive operational experience at airports, we need to question all the airport/airplane-based assumptions in doing so.

Mr. Bonanni commented that we need a conservative vertiport ground infrastructure similar to airport infrastructure until it can be demonstrated to seven 9's that it will be safe.

7. Ground Size: Dimensions. In the agenda, Dr. Leverton had proposed the following categories to be addressed in the AC:

(a) VTOL
Private Vertiport
General Aviation Vertiport (minimum facility)
Public Transport Vertiport (Small/BA609)
Public Transport Vertiport (Large/CTR 2000)

(b) STOL
Private Vertiport
General Aviation Vertiport (minimum facility)
Public Transport Vertiport (Small/BA609)
Public Transport Vertiport (Large/CTR 2000)

Dr. Leverton called the WG's attention to one of the significant changes from the August 22 version to the August 27 version of the discussion paper deals with the issue of "minimum - zero field length" for VTOL transport vertiports. In the August 22 version, he had recommended a rejected takeoff area (RTOA) of 200 feet for a VTOL Transport vertiport (minimum – short field length). In the August 27 version, based on comments from Bell, he recommended that a traditional RTOA should not be required. Still, based on European experience, he acknowledged that an RTOA of zero length could be inadequate but he proposed that this might be best addressed by increasing the size of the FATO from 1.5T (the tip to tip width of the aircraft) to 2.0T and increasing the size of the TLOF from 1.0T to 1.5T. On this second point, Mr. Bonanni commented, that while it may be technically possible to operate with a "zero field length" (i.e., a RTOA of zero length), the FAA may not be willing to invest in such a facility. Although the Industry may be prepared to accept the risk associated with such a facility, the FAA may not be. Mr. Wilkins voiced his agreement with Mr. Bonanni's comments. Dr. Leverton said that if the CTR was capable of operating with a "zero RTOA", surely the vertiport would be adequate to be designed on this assumption.

Mr. Todd questioned what should be the breaking point between transport/small and transport/large. Mr. Bonanni commented that there is rulemaking in process on this issue. Previously, the break point has been 19 passengers. The proposed break point is 9 passengers. As a homework item for all WG members, Dr. Leverton raised the question, "How should we define a transport vertiport?"

Dr. Leverton commented that there was a big jump between a "zero field length" and a STOL operation. One goes from a facility that is a few hundred feet square to a facility that is many hundreds of feet long. There is no clear argument for building a facility somewhere between the two of them in length. Going from one facility to the other requires a significant change in the departure procedure. Mr. Decker voiced his agreement with this comment based on NASA tiltrotor simulation work.

Dr. Leverton commented that he was probably the only WG member with passenger experience flying off the roof of the Pan Am Building in New York City (during the 1970's). A number of passengers were uncomfortable with the backward takeoff procedure used at that facility to minimize risk in the event of an engine failure during takeoff. Even so, it was successfully operated for a number of years. Mr. Askue commented that Sikorsky has four scheduled helicopter airlines operating Cat A around the world (Canada, Sweden, Hong Kong, and Spain/Canary Islands) and they all operate with "zero field lengths". Sikorsky does not use a rearward takeoff. Instead, they accelerate vertically and then, in a smooth transition, they push the nose down and continue to climb. In the event of an engine failure during a departure over water, what the pilots sees looking down is all water. While the pilots are uncomfortable with this possibility, the passengers view it as a benign operation.

8. Vertiport Ground Size: Dimensions. Dr. Leverton suggested that the WG accept the use of the abbreviation "T" as a reference to the tip to tip dimension of the tiltrotor aircraft. In Europe and in other parts of the world, the

abbreviation "D" is used in a similar manner to denote the maximum dimension of the helicopter. After some discussion, the Industry members of the WG recommended that we adopt the abbreviation "D" to refer to the largest dimension of the tiltrotor. The FAA made no comments on this issue.

9. Airspace. In the agenda, Dr. Leverton had proposed the following airspace categories to be addressed in the AC:

1. VFR
2. Non-Precision Point in Space GPS (visual segment)
3. Precision IFR

Mr. Bonanni commented that this list was incomplete. The global positioning system (GPS) provides opportunities for different levels of service, some of which were not possible with the previously available ground-based navigation aids. While this topic is still evolving, current discussions point to a larger list of categories including the following:

a. VFR
b. Nonprecision
c. Nonprecision with vertical guidance
d. WAAS nonprecision
e. WAAS precision

Mr. Bonanni commented that ground space requirements could be different for any of these options that include vertical guidance (options c, d, and e). During the discussion, the topic of missed approach airspace was raised. One WG member commented that TERPS missed approach airspace requirements were so complex that the current Heliport and Vertiport Design AC's do not address them at all. Certainly the facility design AC's can refer to the TERPS order, however, it is an arcane document written for those develop TERPS procedures. The TERPS order is indecipherable by most readers of the Heliport and Vertiport Design AC's. While it will be a challenge to address missed approach airspace requirements in the Heliport and Vertiport Design AC's, it would be considerably more challenging to rewrite the entire TERPS order in plain English.

10. Other Business. In a discussion of vertiport lighting, several members expressed concern that current FAA heliport and vertiport lighting recommendations are inappropriate and that this will unnecessarily constrain the growth of IFR helicopter and tiltrotor operations. Mr. Smith expressed sympathy for these concerns. He called to the member's attention the international Heliport/Vertiport Lighting Conference that the FAA had hosted in January 1999. At this conference, the FAA invited the helicopter industry, the aviation lighting industry, and other aviation authorities to advise us on how best to proceed with heliport/vertiport lighting research and development. The work that needs to be done is large; the available resources few. How best can the FAA proceed so that we will accomplish Industry's highest lighting priorities over the next several years? While this conference was very useful, not all questions have been answered. Mr. Smith informed the WG that the FAA continues to welcome Industry's advice on how best to proceed.

11. Schedule for the Vertiport Design AC. The FAA has previously announced their intention to combine the Heliport Design AC and the Vertiport Design AC into one document. For reasons of administrative efficiency, this is still the FAA's intent. When the Heliport Design AC is next revised, it will be published as part of a combined Heliport/Vertiport document. When the Vertiport Design AC is next revised, it may be published as part of a combined Heliport/Vertiport document but this is dependent on timing.

Although the current revision of the Heliport Design AC will not be released for public comment until perhaps November 1999, the FAA and Industry have already agreed that there are other revisions needed in this document. These revisions are not yet of sufficient maturity to be included in the AC. Additional work must be done. Two issues of great interest are:

Helicopter performance and its effect on VFR approach/departure airspace requirements

Ground infrastructure requirements to support IFR heliport operations

The timing of this work, and potentially other efforts, could lead the FAA to publish one more stand-alone Vertiport design AC.

12. **Next Meeting - Date and Place.** The WG chose a tentative date of December 8 for the next meeting. The meeting is planned to be in either Fort Worth TX or Washington DC. Dr. Leverton suggested that the FAA provide the WG with a TERPS briefing at the next meeting.

Summary of Action Items from This WG Meeting

Mr. Todd volunteered to provide BA609 performance data in about 30 days. These performance data will be based on the Bell BA609 simulator evaluation.

All WG members should review Dr. Leverton's discussion paper entitled Vertiport Design [Issue 5 dated 27 August 1999]. This paper will be discussed at the next meeting.

All WG members should consider the question, "How should we define a transport vertiport?"

All WG members should consider the question, "How best can the FAA proceed on heliport/vertiport research and development so that we will accomplish Industry's highest lighting priorities over the next several years?

Mr. Bonanni will request that FAA Flight Standards provide a TERPS briefing at the next WG meeting.

Outstanding Action Items from Prior Working Group Meetings

Mr. Heneault commented on the need to use standard International terminology in the design AC and he volunteered to draft a proposal on terms and definitions.

Several WG members recommended that the FAA look toward adopting standardized terminology regarding the tiltrotor. **Mr. Wilkins** volunteered to develop a paper on this topic.

Mr. Reber volunteered that Bell Helicopter would write a paper proposing a revision of the definition of a vertiport.

The WG members will consider whether the current Vertiport Design AC can remain as it is until the next revision is available or whether the current AC provides advice that is either dangerous or so significantly inappropriate that some other action should be considered. In this regard, WG members should identify specific issues in the current AC and the specific problems that they present. To date, no significant issues have been raised.

In considering the vertiport rollway and the minimum vertiport FATO/TLOF, Dr. Leverton commented that there would be a need to "blend" the two types of facilities. Perhaps the AC should address how the design requirements transition from one case to the other. **Dr. Leverton** volunteered to consider how this might be done. [This topic has been addressed in an Industry position paper entitled Vertiport Design (Issue 5 dated 27 August 1999). As discussed elsewhere in these minutes, it does not appear practical to "blend" the two types of facilities.]

Dr. Leverton will draft a letter for AHS signature expressing Industry's opinion that FAA should publish the VERTAPS report quickly so that it may be used by this WG.

<u>Rejected Takeoff Performance</u>. The **manufacturers' WG representatives** have made a commitment to provide the WG with the information on rejected takeoff requirements of the CTR2000 and the BA-609. Bell and Boeing have verbally provided initial estimates of the TLOF length required for the BA-609 and the CTR2000 under certain operational scenarios. (Previously, the WG had concluded that this issue should be revisited after the FAA announces its decision on certification basis and the associated rules. Since the FAA and Bell have agreed upon the certification basis, this revisitation could now take place.)

<u>Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts</u>. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will significantly shorten the life of the concrete surface. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BA-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material. Based on XV-15 data, Bell has provided an <u>estimate</u> of ground temperatures under the BA-609 exhaust. These data have raised significant questions that the manufacturers have not yet answered. When it becomes available, measured data on the BA-609 will be of great interest. In addition, similar data are still needed for the V-22 and the CTR2000.

<u>Airspace Issues</u>. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. **The manufacturers need to provide** the WG with CTR departure profiles. [Dr. Leverton has discussed this issue with Bell and their inputs are now awaited.]

<u>Document Availability</u>. **Mr. Wilkins** volunteered to pursue whether CTR Missions and Applications Phase II study could be made available to the entire WG. Currently, this is a proprietary document, available only to Government agencies and the manufacturers.

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
January 28, 1999

Attendance

Bill Decker, NASA Ames	Scott Shollenberger, FAATC
B Hooper Harris, FAA	Robert D. Smith, FAA
Guy Heneault, Transport Canada	Ray Syms, Consultant
Dr. John Leverton, Industry Co-chairman	Alan Todd, Bell Textron
Norm Mowbray, Bell Textron	Ryan Wilkins, Boeing Helicopter
Ron Reber, Bell Textron	Steve Winter, FAA
Bill Sanderson, HAI	John Zugschwert, Bell Textron

Minutes

1. **Co-Chairman's Remarks**. Dr. Leverton chaired the meeting and briefly addressed today's agenda. Mr. Zugschwert welcomed the participants.

2. **Heliport Design AC Status**. Since Mr. Bonanni was absent, there was no discussion of this item at today's meeting.

3. **CTR Certification Basis, Performance Requirements**. As discussed at the previous WG meeting, the FAA and Bell have reached an agreement on the certification basis. Discussions with other certification authorities are underway. While some changes to the certification basis are likely as the process progresses, it appears unlikely that these changes will have significant impact on the deliberations of this WG.

4. **Vertiport Categories**. Dr. Leverton led the WG through a discussion of vertiport categories including the following:

General Aviation Vertiport (minimum facility)
Transport Vertiport (Small/BA609)
Transport Vertiport (Large/CTR 2000)

For the 40-passenger CTR, Dr. Leverton recommended that the WG should use the data developed by the Civil Tiltrotor Development Advisory Committee (CTRDAC), assuming STOL operations. No one objected to this proposal.

Dr. Leverton raised the question of whether we should address only a General Aviation (GA) Vertiport for the BA609. Messrs. Sanderson and Heneault recommended that the WG should follow the same philosophy as that being applied to the Heliport Design AC. Mr. Heneault commented that Canadian heliport design regulations do not address GA and public heliports separately. Canada only addresses minimum safety requirements. Any larger design is based on operational economics.

Dr. Leverton commented that the FAA Certification Directorate has concluded that the tiltrotor will fly like a helicopter in the vicinity of the landing site. Thus, he recommended that the WG should adopt the same basic dimensions contained in the Heliport Design AC. Mr. Smith took exception to this recommendation. Over the last 15 years, as the FAA has attempted to validate specific heliport design dimensions initially established decades ago, the agency has concluded that some of these dimensions are inadequate and has proposed that they be increased. Industry has generally opposed any increase in dimensions, arguing that the economics impact of modifying many thousands of heliports is more than what Industry could afford. Thus, the dimensions in the design AC are a political and economic compromise. As we address the tiltrotor and the associated vertiport design requirements, we should not be constrained by the argument that we've always done it this way and we can't afford to change. After all, Industry is not dealing

with thousands of existing vertiport and the cost to rehabilitate them. The number of existing vertiports is a very small, one-digit number.

Mr. Smith commented that the tiltrotor is a new category of aircraft capable of flying like a helicopter and like and airplane. While it is expected to operate in ways that are similar to a helicopter during approach, departure, and ground maneuvers, these tiltrotor operations will not be identical to helicopter operations. The WG should look carefully at the design requirements associated with tiltrotor operations without being constrained by the baggage of today's heliports. The BA 609 is not an R-22 and a vertiport should not be defined like the heliport in the backyard of an R-22 owner.

Mr. Smith also commented that since the tiltrotor is a new category of aircraft, there is very little operational tiltrotor experience from which we can learn. We can, however, look to helicopter and airplane operational experience and seek to understand how this experience should be reflected in landing site design recommendations. Since the number of existing tiltrotors is so small and the number of vertiport operations to date is miniscule, we can not look to this operational experience to guide us in vertiport design deliberations. We can, however, look to operational experience at both heliports and airports and seek to understand what this experience has taught us and how it should be applied to vertiport design recommendations.

5. <u>Vertiport Ground Size: Aspects to be Considered</u>. Dr. Leverton led the WG through a discussion of aspects to be considered including the following:

> VFR, Non-precision (NPA), Precision IFR
> VTOL/STOL

Does the NPA require a different size TLOF than what would be required at a VFR vertiport? Messrs. Decker and Todd stated their opinion that it did not. No objections were voiced on this issue. The WG did not address the TLOF size requirements associated with a precision approach. The WG recognized that a STOL TLOF and a VTOL TLOF will have different dimensions and that an extended TLOF is a rollway.

Does the FATO include the rejected takeoff area (RTOA) or should this be a separate area? Dr. Leverton suggested that the WG should treat these areas separately. The WG discussed this issue but made no decisions as a result. Mr. Decker commented that the RTOA required for VTOL operations is longer than what is required for STOL operations. He noted that this is unique for the tiltrotor and perhaps for the tiltwing as well. The tiltrotor is different than the helicopter in this regard. (This difference is due to the greater acceleration capability with thrust vectoring (nacelle tilt) of the tiltrotor in comparison with a helicopter.)

Does the NPA require a different size FATO than what would be required at a VFR vertiport? Mr. Heneault commended that, under Canadian regulations, the minimum recommended FATO size is the same at VFR heliport and heliports with a NPA. He noted that the same could be said about the safety area. The WG recognized that the minimum size of the FATO will be larger at a landing site with a precision approach.

The WG discussed the terms: protection zone, clearway, and stopway and the differences in the associated design requirements. Dr. Leverton commented that the FAA is not consistent with ICAO and the rest of the world on this issue. Mr. Reber recommended that the FAA should be consistent with ICAO on this issue. The WG made no specific recommendations on these terms.

Dr. Leverton commented that, for an S-76 on a standard day at 90% maximum gross weight, the FATO plus RTOA plus clearway requirements total approximately 1500 feet.

A member commented that, currently, there is no US regulation requiring Category A operations unless the aircraft is only certified for Category A operations. This is only the case for helicopters of greater than 20,000 pounds.

Looking at the LAAS Critical Area ground area requirement defined in Mr. Bonanni's paper presented at the previous meeting, Dr. Leverton commented that this was a significant amount of space. In Mr. Bonanni's absence, the WG did not discuss this issue.

6. **<u>Vertiport Ground Size: Dimensions</u>.** Dr. Leverton led the WG though a discussion of vertiport ground space components. This discussion was framed by the structure of the proposal made by Dr. Leverton at the last WG meeting (see the figure below) and by the dimensions of the "Typical Vertiport" figure contained in Mr. Bonanni's paper presented at the last meeting.

Mr. Decker stated that VTOL operation implies hover-out-of-ground-effect (HOGE) capability or hover-in-ground-effect capability using "backward takeoff" procedures. Once the aircraft loses the capability to hover on one engine, there is a requirement for additional concrete (longer TLOF).

Messrs. Decker and Leverton suggested that the AC needs a discussion of the basis for the 600-foot FATO. Under the worst case conditions, the 600-foot FATO does not give you adequate RTOA. Therefore, additional length will provide additional operational flexibility. The RTOA need not be a paved surface if the operator is prepared to accept damage to the aircraft (and increased risk of personal injury). Under this assumption, the brake release is a commitment to takeoff. If the tiltrotor lose one engine on takeoff, the pilot will still depart with a reduced climb gradient. This leads to a need for the AC to address the tradeoff between the reduced climb gradient and the longer FATO.

There is also a continuum of performance/facility size between VTOL transport performance and STOL performance. This issue needs to be discussed in further depth.

Dr. Leverton questioned the WG regarding protection zones/clearways. What should be provided at a vertiport? How large does it need to be? For a precision approach facility, he suggested that this area should be clear of obstacles. For a VFR facility, he suggested that a few obstacles would be permissible. For a NPA facility, he suggested that this issue is still subject to discussion.

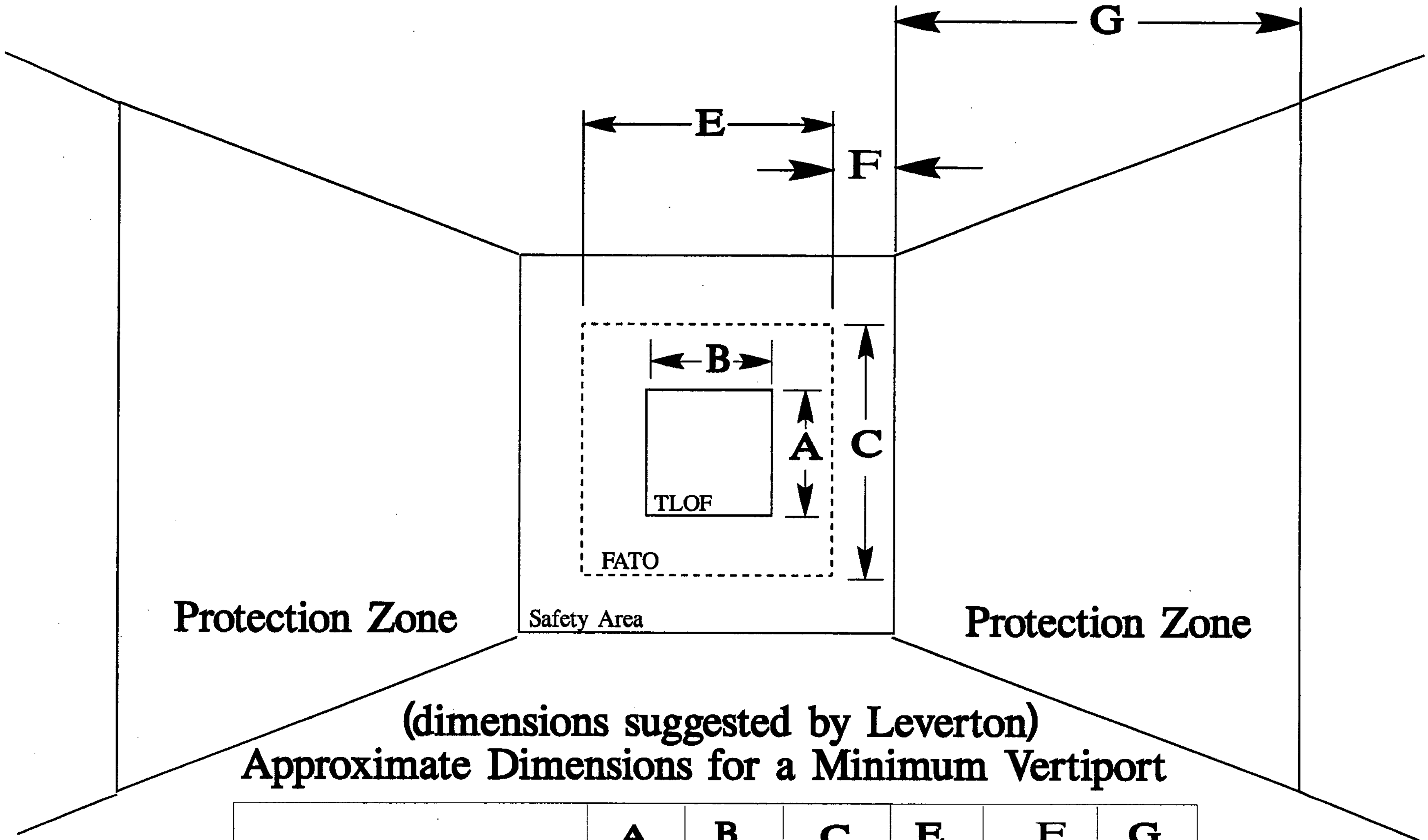
Dr. Leverton question the basis of the 1000-foot length of the rollway protection zone (RLPZ) proposed by the FAA in Mr. Bonanni's paper. Mr. Syms commented on his involvement with an accident analysis conducted by SCT for the FAA several years ago. With civil accident, the NTSB accident reports generally did not identify the exact location of obstacles with which helicopters had collided. With military accidents, Army accident data shows that helicopters are hitting wires and other hard-to-see objects close to the heliport.

Mr. Decker asked for an explanation of the purpose of this protection zone/clearway. Is it intended to be a level acceleration zone or the area under a sloped departure surface? Looking to airports for their experience on a very similar design component, what are the purposes of the runway protection zone and the runway safety area? No one in the WG was prepared to provide definitive answers to these questions.

Mr. Heneault commented on the need to use standard International terminology in the design AC and he volunteered to draft a proposal on terms and definitions.

The WG discussed the term "vertiport" and whether it was possible to improve on the current AC definition. The WG agreed that, in the definition of a vertiport, the use of the term "rotorcraft" is inappropriate since it includes both helicopters and gyrocopters. As a replacement, the words "helicopters that are suitably certified and equipped" were proposed. The Mr. Reber volunteered that Bell Helicopter would write a paper proposing a revision of the definition of a vertiport.

Several WG members recommended that the FAA look toward adopting standardized terminology regarding the tiltrotor. It was noted that the term "powered lift" is not heavily used in the current Vertiport Design AC. Several WG members stated their opinion that a vertiport is not intended to accommodate the landing of a fan-in-wing aircraft. Mr. Wilkins volunteered to develop a paper on this topic.



(dimensions suggested by Leverton)
Approximate Dimensions for a Minimum Vertiport

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VTOL/VFR GA Vertiport	1 D	1 D	1.5 D	250'	1/3 D or 20'	280'
VTOL/VFR Transport Vertiport	1 D	150'	1.5 D	250'	1/3 D or 20'	400'

7. **Airspace.** What airspace is required at a vertiport? Mr. Heneault commented that airspace requirements should be a function of aircraft performance. In response to a question from Mr. Smith, the WG confirmed its previous decision that the minimum recommended vertiport airspace will be based on tiltrotor requirements. That is, if a particular helicopter model can operate safely within the airspace required by the tiltrotor, they will be welcome to operate at the vertiport. If a particular helicopter model is not capable of operating safely within the airspace required by the tiltrotor, they will effectively be excluded from operation at vertiports. The WG has previously concluded that the AC should not recommend that vertiports be designed to accommodate all helicopters.

In response to a question, Mr. Reber stated that the BA609 will not be available as a VFR-only aircraft. However, while all BA609 will be certified and equipped for IFR flight, some users will operate the aircraft as a VFR aircraft, at least part of the time.

Mr. Wilkins raised a question on what regulations will the tiltrotor be required to follow in terms of minimum altitude, helicopter regulations or airplane regulations. Since FAA decisions on such issues have not yet been made, no answer was available for this question. Mr. Decker commented that, due to the reaction time required in the event of a failure, it would not be good to operate the tiltrotor in "airplane mode" below 1500 feet AGL. Operations in airplane mode below 1500 feet should be conducted with the same concern for suitable forced-landing areas that applies to conventional fixed-wing airplanes. With less than 1500 feet of altitude, a tiltrotor pilot is unlikely to have sufficient reaction time to perform a conversion to helicopter mode for a confined-area landing in the event of a total engine failure. Recovery from such a remote event (implies both/all engines have failed in a multi-engine aircraft) will lead to an airplane-mode dead-stick landing, with aircraft damage (such as the rotors) likely. The 1500 feet AGL operation is a recommended practice that confers additional recovery options that minimize damage potential to the aircraft and to objects on the ground. Such recoveries are similar to multi-engine helicopter recoveries.

8. **Other Business.** Mr. Wilkins announced that Boeing Helicopter would be active in this WG for at least the next 12 months.

9. **Schedule for the AC Revision – Update.** The WG did not discuss this issue.

10. **Next Meeting - Date and Place.** The WG did not pick a date or location for the next meeting.

Summary of Action Items from This WG Meeting

Mr. Heneault commented on the need to use standard International terminology in the design AC and he volunteered to draft a proposal on terms and definitions.

Several WG members recommended that the FAA look toward adopting standardized terminology regarding the tiltrotor. Mr. Wilkins volunteered to develop a paper on this topic.

Mr. Reber volunteered that Bell Helicopter would write a paper proposing a revision of the definition of a vertiport.

Outstanding Action Items from Prior Working Group Meetings

The WG members will reconsider their preferences on the matter of schedule for publication date of the revised Vertiport Design AC (will be a combined Heliport/Vertiport Design AC).

The WG members will consider whether the current Vertiport Design AC can remain as it is until the next revision is available or whether the current AC provides advice that is either dangerous or so significantly inappropriate that some other action should be considered. In this regard, WG members should identify specific issues in the current AC and the specific problems that they present. To date, no significant issues have been raised.

In considering the vertiport rollway and the minimum vertiport FATO/TLOF, Dr. Leverton commented that there would be a need to "blend" the two types of facilities. Perhaps the AC should address how the design requirements transition from one case to the other. **Dr. Leverton** volunteered to consider how this might be done.

Dr. Leverton will draft a letter for AHS signature expressing Industry's opinion that FAA should publish the VERTAPS report quickly so that it may be used by this WG.

Rejected Takeoff Performance. The **manufacturers' WG representatives** have made a commitment to provide the WG with the information on rejected takeoff requirements of the CTR2000 and the BB-609. Bell and Boeing have verbally provided initial estimates of the TLOF length required for the BB-609 and the CTR2000 under certain operational scenarios. (Previously, the WG had concluded that this issue should be revisited after the FAA announces its decision on certification basis and the associated rules. Since the FAA and Bell have just recently agreed upon the certification basis, this revisitation could now take place.)

Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will significantly shorten the life of the concrete surface. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BB-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material. Based on XV-15 data, Bell has provided an estimate of ground temperatures under the BB-609 exhaust. These data have raised significant questions that the manufacturers have not yet answered. When it becomes available, measured data on the BB-609 will be of great interest. In addition, similar data are still needed for the V-22 and the CTR2000.

Airspace Issues. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. **The manufacturers need to provide** the WG with CTR departure profiles. Dr. Leverton has agreed to pursue this issue with Bell.

Document Availability. **Mr. Wilkins** volunteered to pursue whether CTR Missions and Applications Phase II study could be made available to the entire WG. Currently, this is a proprietary document, available only to Government agencies and the manufacturers.

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
October 14, 1998

Attendance

Robert Bonanni, FAA Co-Chairman
Vaughn Askue, Sikorsky
Dr. John Leverton, Industry Co-chairman
Norm Mowbray, Bell Textron
Bill Sanderson, HAI
Gary Stevens, Illinois DOT
Robert D. Smith, FAA
Ray Syms, Consultant
Alan Todd, Bell
Jim White, FAA

Minutes

1. Co-Chairman's Remarks. Mr. Bonanni chaired the meeting and welcomed the participants. Dr. Leverton made opening remarks about the need to keep the momentum moving forward. He stated his opinion that it is time to start trying to define numerically the approximate size of different vertiport design components so that Industry can consider the implications involved. He also asked that the working group (WG) consider whether when we should define the design requirements of a VFR-only vertiport.

2. Heliport Design AC Status. Since the majority of the attendees had attended a meeting on this topic on October 13, there was no discussion of this item at today's meeting.

3. CTR Certification Basis, Performance Requirements. Mr. Smith offered his congratulations to Bell Helicopter and the FAA Rotorcraft Certification Directorate for their success in coming to a consensus on the certification basis for the Bell 609. A document (Bell 609 Certification Basis, dated 27 August 1998) addressing the details of this consensus is now available. FAA/Bell discussions on this matter have been in process for a little over two and a half years. During this time, Bell has made several written requests for the certification of the 9-passenger tiltrotor. Each letter to the FAA contained adjustments to the requested certification basis. The first letter requested that the aircraft be certificated as a Transport vehicle. Along the way, both parties concluded that certification to Transport Category only would not be appropriate. The Rotorcraft Certification Directorate has indicated that the Bell 609 is being considered for a "Special" certification. The FAA Rotorcraft Certification Directorate is now scheduling meetings with certification authorities in Canada and Europe. Some adjustments may be made to the Bell 609 Certification Basis document as the certification basis progresses. The FAA Certification Directorate does not plan to formally publish this document until approximately six months prior to the anticipated certification date.

Dr. Leverton commented that the "near-in" material is based on FAR Part 29 with Category A and Category B performance, and that the terms "Transport Category" and "Normal Category" are used in the Bell 609 Certification Basis document. In response to a question, several Industry members responded that specific civil tiltrotor operations regulations have not been developed. Mr. Todd commented that both "vertical" and STOL operations will be available for both Transport and Normal Category operations. Dr. Leverton stated his understanding that the Bell 609 will primarily operate as a VSTOL aircraft but that STOL operations will also be allowable.

Mr. Stevens commented that one of the missions for the Bell 609 would be air ambulance operations. Mr. Smith added that Bell has indicated that three 609's have been ordered for air ambulance use, one in Australia, one in Germany, and one in the USA (Omniflight). As a result, it will be appropriate to consider whether hospital vertiport design recommendations should differ in any respects from the guidance for other types of vertiports.

Previously, Mr. Smith had expressed reservations about the difficulties in developing revised vertiport design guidance if even the certification basis of the Bell 609 tiltrotor was not defined in detail. Thus, in Mr. Smith's opinion, the availability of this document represents a tremendous step forward. Both Bell and the FAA Certification Directorate are to be complimented for their work.

The Working Group discussed whether it would be helpful to receive a briefing on the certification basis from both Bell and the FAA. While this may be desirable after the WG members become much more familiar with the document, the WG decided that it would be premature to schedule the next WG meeting in Fort Worth.

4. Homework Status Reports.

a. Vertiport design equivalent to airport design safety margins

Mr. Bonanni presented a vertiport design based upon airport design safety margins for an airplane roughly comparable to the Bell 609 in size and approach airspeed. The aircraft used was a small (less than 12,500 pounds) utility airplane operating at XX knots. The runway length of 2400 feet was cut to a rollway length of 600 feet based on the recommendations of Bill Decker, NASA Ames. Although building setback lines have not been shown on the drawing presented, the use of such lines is appropriate. This is a first cut and the FAA makes no claims that this design is appropriate in all respects for the unique characteristics of the tiltrotor.

Mr. Bonanni provided a short explanation of certain terms such as runway protection zone (RPZ) and instrument procedure/vertical guidance (IPV). He also discussed ground space requirements for a local area augmentation system (LAAS) ground station. For the equivalent of Category 2 operations, he commented that this might require more than one LAAS ground station. In a discussion of point-in-space approaches, Mr. Bonanni stated that there will be a requirement for ground infrastructure. He also pointed out that, for vertiport point-in-space approaches, where the weather alternate is a major airport, there may be air traffic control (ATC) concerns regarding airport capacity and delay issues.

Mr. Smith reminded the WG of the reasons for the assignment of this "homework" item. FAA airport design recommendations have evolved over a period of many decades. Today's airport design recommendations are based upon a wealth of operational experience, accident experience, and research. We don't have comparable experience for tiltrotors. What have airport designers learned over many decades of IFR operations? How have airport design recommendations been modified to address these lessons learned? Can we translate this into something that fits the CTR situation? We would do well to learn from both airport and heliport experience as separate approaches toward understanding vertiport design requirements.

Mr. Smith commented that, if Industry believes that other dimensions would be more appropriate than those in the drawing developed by Mr. Bonanni, they should develop a written justification for their proposal rather than relying solely on oral discussion within the WG. Looking back on the history of the Heliport Design AC, prior to the FAA research starting in the mid-1980's, there is no written basis for many of the numerical values included in these design recommendations. It would be unfortunate if, in a few years, we find ourselves in a similar position with regard to vertiport design recommendations. The FAA's vertiport design recommendations can be expected to evolve relatively rapidly during the next decade. As this evolution takes place, both the FAA and Industry are likely to have questions on the basis for the original design guidance. We should conduct ourselves in a way that provides a written record of our rationale for the specific dimensions of vertiport design parameters.

b. Rollway versus FATO/TLOF design requirements, how should the design requirements transition from one case to the other? This topic was not discussed.

c. Schedule for AC Development – Discussion. Although the WG discussed this topic briefly, they did not come to a consensus on a new schedule. Mr. Bonanni commented that he did not expect to see the Heliport/Vertiport AC published before the summer of 2000. Dr. Leverton expressed a hope that we could have a rough draft of the AC by October 1999 and a polished draft for public review and comment by January 2000. Mr. Smith commented that, with the departure of Boeing as a partner on the 609, the delivery of the first 609 aircraft will be delayed. Bell expects to provide their 609 customers with a revised schedule and cost by the end of this calendar year. With this in mind, Mr. Smith suggested that the WG should address the schedule for revision of FAA vertiport design guidance after Bell has announced their new 609 delivery schedule. Dr. Leverton did not agree and he argued that vertiport designers need this information today.

5. Tiltrotor Rotorwash.

This item had been placed on the agenda with the expectation that the FAA would be ready to distribute copies of the tiltrotor rotorwash white paper being prepared by Mr. Sam Ferguson. However, this document is not yet complete. Mr. Smith expressed confidence that this paper would be available by the end of October. The FAA will distribute the document when it becomes available. (It has since been mailed to Working Group members.)

Commenting on a related topic, Mr. Bonanni stated that the Bell XV-15 data on engine exhaust temperatures indicates that the XV-15 would require that vertiports have special pavement and special joint compound in order to tolerate the heat. In view of the added expense involved, this places greater emphasis on the need to obtain similar data on the Bell 609.

Mr. Stevens commented that an XV-15 had set the grass on fire during a demonstration landing at McCormick Place in Chicago. He also stated that the City of Chicago is expected to close Meigs Field in the foreseeable future. (Meigs Field is an ideal location for tiltrotor operations into downtown Chicago.)

Mr. Syms commented that a particular model of helicopter was banned from a heliport in Cherry Hill NJ because it burnt the grass during a two-minute engine cool down.

Mr. Smith reminded the WG that the FAA is concerned about the potential effect of tiltrotor exhaust on the life of the concrete in vertiport rollways, TLOF's, FATO's, taxiways, and aprons. Portland Concrete typically lasts 20 years. Anecdotal information seems to indicate that tiltrotor engine exhausts will not adversely affect a concrete surface. However, anecdotal information does not answer our questions about long-term effects. After a number of vertiports have been built, it would be expensive to learn that tiltrotor engine exhaust will shorten the life of the concrete surface from 20 years to only 5 or 10 years. If tiltrotor exhausts shorten this life by this amount, the replacement expense would be huge. The Working Group needs to do its homework so that the appropriate design guidance on this issue can confidently be developed.

6. Vertiport Size Requirements.

Dr. Leverton led the WG though a discussion of vertiport ground space components. Specifically, what components are needed beyond the TLOF and FATO/Rollway? The WG recognized the need for a safety area and a protection area. Dr. Leverton suggested that, in gaining an understanding of the relative size of the various vertiport components, we might come to see that the size of one component gives us a different perspective about the importance of the size of another component. As an example, if we consider the length of the rollway and the safety zones and protection zones on both ends, we may conclude that the minimum separation between gates is less important than what was previously thought. With this in mind, he suggested that we start with the vertiport configurations (VTOL, STOL, etc.) discussed during previous meetings and add to them our best guess of the approximate size of other vertiport ground space components.

Dr. Leverton proposed, for talking purposes, that we use the heliport safety zone and protection zone dimensions currently being discussed by Industry and the FAA within the context of negotiations on the revision of the Heliport Design AC. The FAA made no comments on the appropriateness of using these heliport dimensions at a vertiport. (One should recognize, however, that negotiations on minimum heliport design recommendations are influenced by Industry fears that an increase in the FAA's recommendations might lead one or more of the 50 States to close existing heliports that are not in compliance. While the FAA views this as unlikely, it is difficult to predict what 50 States might choose to do. With vertiports, however, such concerns are moot. Thus, the Working Group is free to choose vertiport dimensions that are different from heliport dimensions. Vertiport design dimensions should be based on what is needed, not on what is available.)

As an example of his suggested approach, Dr. Leverton drew a sketch of the VTOL vertiport showing the TLOF, FATO, safety zone, and protection zone for a "private use" and a General Aviation vertiport. A similar drawing should be done for the STOL vertiport.

During a discussion of Bell 609 certification requirements and performance, Dr. Leverton commented that Category A pad requirements are typically 2.0 OL (2 times the overall length of the design helicopter). Mr. Todd commented that flight manuals, in fact, vary in their recommendations from 1.5 OL to 3.0 OL. He also pointed out that these flight manuals are published after consultation with the certification authority.

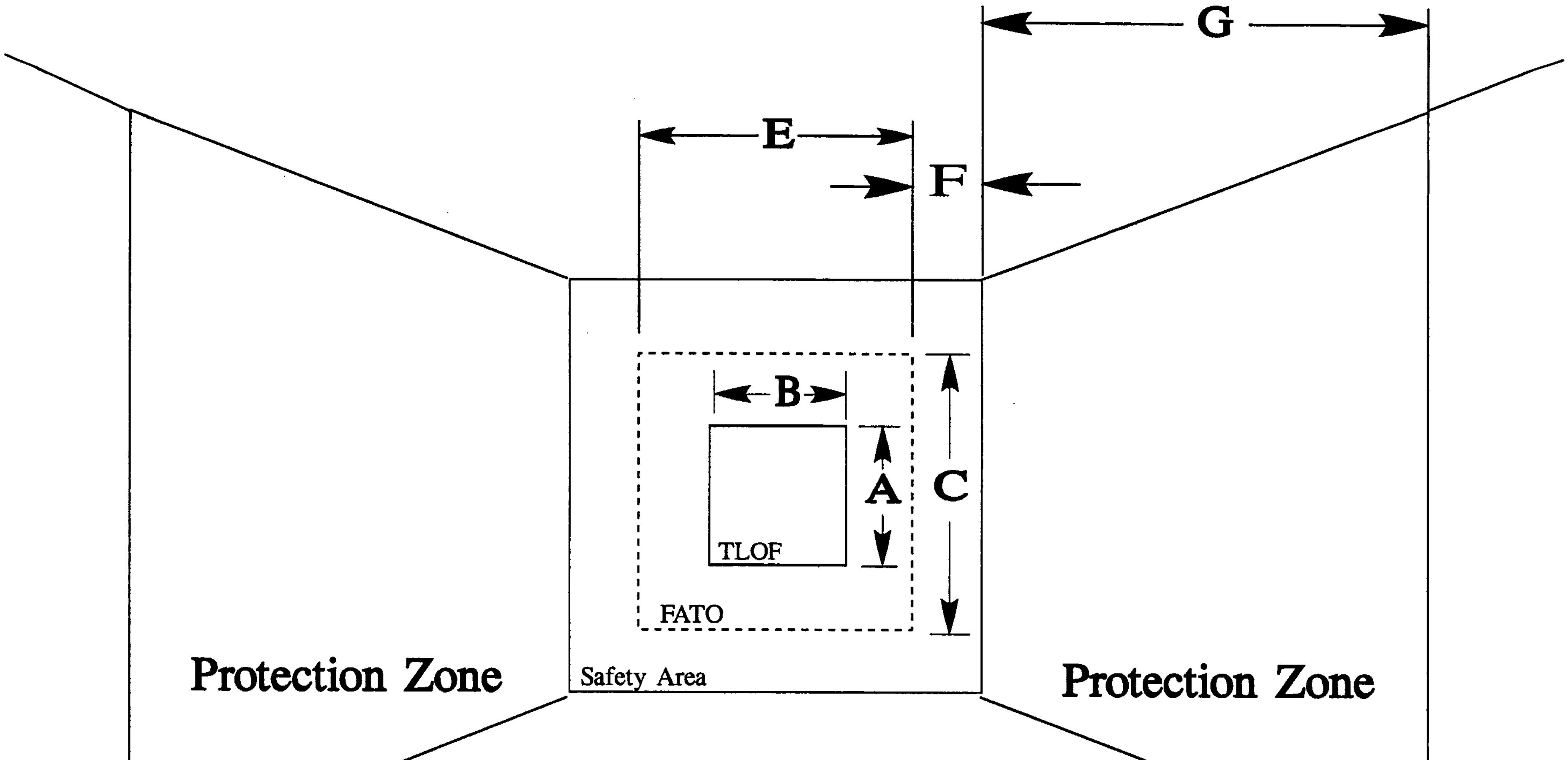
In discussing a vertiport located on a rooftop or pier, Industry questioned whether the FATO of a minimum vertiport facility needs to be load bearing. The FAA did not argue that the vertiport FATO design philosophy should be different from the heliport FATO design philosophy (which does not recommend that the FATO must always be load bearing). Mr. Bonanni cautioned the WG, however, that the FAA's vertiport design recommendations will be based on requirements for safe operations, not on what is available today. One WG member asked rhetorically if NASA will agree that the FATO need not be load bearing, recognizing that there is a loss of performance as a result. (The NASA member of this WG was not in attendance to answer this question.)

Dr. Leverton asked that the working group (WG) consider whether when we should define the design requirements of a VFR-only vertiport. The WG agreed that the FAA vertiport design recommendations should address the VFR-only vertiport in addition to non-precision and precision vertiports.

In the Heliport Design AC, the minimum recommended ground requirements for heliports with non-precision approaches are not significantly different from those of VFR heliports. A WG member asked if this would continue to be the case. Mr. Bonanni responded that this probably would not continue to be the case. Mr. Smith reminded the WG that, in the 1988 Heliport design AC, the minimum recommended non-precision approach/departure airspace was the same as the minimum recommended VFR approach/departure airspace. However, upon closer scrutiny, the FAA concluded that significantly larger airspace is required to support non-precision operations and Industry agreed. Upon closer scrutiny, the FAA is likely to come to the same conclusions regarding the size of certain ground space requirements for both heliports and vertiports.

7. <u>Next Meeting - Date and Place.</u>

The WG decided to hold the next meeting on Wednesday January 20 in Washington DC.
Dr. Leverton and Mr. Todd will coordinate with Bell Textron on the location of the next meeting.



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Airspace Issues. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. **The manufacturers need to provide** the WG with CTR departure profiles. Dr. Leverton has agreed to pursue this issue with Bell.

Taxiway Width/Parking Clearances. **Mr. Heneault** volunteered to provide Canadian criteria developed for helicopters, suggesting that they might be applicable to CTR.

Document Availability. **Mr. Wilkins** volunteered to pursue whether CTR Missions and Applications Phase II study could be made available to the entire WG. Currently, this is a proprietary document, available only to Government agencies and the manufacturers.

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
August 20, 1998

Attendance

Robert Bonanni, FAA Co-Chairman
Vaughn Askue, Sikorsky
William Decker, NASA Ames
Sam Ferguson, EMA
Dr. John Leverton, Industry Co-chairman
Norm Mowbray, Bell Textron
Bill Sanderson, HAI
Robert D. Smith, FAA
Alan Todd, Bell

Minutes

1. Opening Remarks.

Mr. Smith spoke of the contractual constraints that have led to this "abbreviated" Working Group meeting. The only scheduled agenda item for this meeting is the results of tiltrotor rotorwash research and analyses. The FAA is particularly interested in Industry feedback on any additional work that should be done on this subject prior to the end of our contract (September 30).

The majority of civil helicopters are light in weight and it is rare for them to cause a rotorwash-related mishap. As rotorcraft increase in weight, they are capable of generating greater rotorwash. Thus, with heavy rotorcraft, rotorwash-related mishaps are more of a concern. The assurance of safety is the responsibility of the pilot. When this fails, the operator is responsible for damages and presumably takes appropriate action to preclude future mishaps.

Anticipating the introduction of tiltrotor and large helicopters (such as the EH-101 and the S-92), the FAA has questioned whether protection against rotorwash mishaps should continue to depend so heavily on pilot judgment. Would it not be better to provide a larger safety margin by addressing this issue via facility design and operational procedures? This is the avenue that the FAA has been pursuing.

The FAA approach to this task has been four-fold:

a. Measure rotorwash of existing helicopter and vertical flight aircraft such as the tiltrotor. Make use of data collected by other government agencies.

b. Develop and validate a rotorwash computer model based on the available rotorwash data.

c. Analyze rotorwash-induced mishaps and determine the thresholds at which rotorwash becomes a potential hazard. Previous analysis (FAA/RD-90/31) indicates that at least two thresholds are of interest. The threshold for personnel should be based on overturning forces and moment limits. The threshold for other types of hazards (such as overturning small airplanes) should be based on rotorwash peak wind speed.

d. Apply the model to an analysis of a variety of operational scenarios using this threshold(s) and determine how to alleviate this type of mishap by avoiding these potential hazards.

At an earlier meeting, the WG concluded that the tiltrotor would ground-taxi rather than hover-taxi. Since all tiltrotor data collected to date had been for hovering aircraft, the FAA has been seeking to obtain tiltrotor rotorwash with the aircraft on the ground. Bell Helicopter has provided XV-15 rotorwash data collected during ground-taxi operations. The FAA has also obtained the extensive V-22 data collected at Patuxent River MD. Today's presentation is based on the analyses of these data.

For a number of years, Mr. Ferguson has supported the FAA in their consideration of rotorwash issues. During this time, he has authored a number of FAA technical reports. The most important of these is the two-volume Rotorwash Analysis Handbook (FAA/RD-93/31). Also of great interest is Analysis of Rotorwash Mishaps (FAA/RD-90/17).

Prior to the meeting Mr. Smith had circulated copies of white paper entitled CTR Rotorwash – Hazard Threshold for Civilian Passengers. This paper is heavily based on section 5 of FAA/RD-93/31. Working Group members are encouraged to read the FAA/RD-93/31 document in its entirety if they have not already done so.

2. Tiltrotor Rotorwash.

Mr. Ferguson provided a brief history of rotorwash analysis studies going back to the early 1960's. Initially, this effort focused on military operational issues. FAA research started in the late 1980's. In measuring rotorwash, one of the key lessons learned is that the choice of sensor is critical. Early measurements using mechanical sensors are of very limited interest. U.S. Navy testing at Patuxent River has used ion beam or acoustic sensors. These are the only current sensors that can provide high quality data.

Rotorwash mishap analysis has identified a number of issues of concern. These include overturning forces on personnel, effects on nearby aircraft, effects on ground vehicles and structures, hazards involving entrained objects and debris, and others. The majority of rotorwash related mishaps could be avoided if separation distances are maintained so that the impacting rotorwash generated velocities do not exceed 30 knots. Overturning force on personnel is a more complicated issue, however, and it needs to be addressed in separately.

Mr. Ferguson talked briefly about the rotorwash model that he developed under contract to the FAA. However, he emphasized that all of the data presented today is based on measured data. He also stated that he would discuss the physics of the tiltrotor rotorwash but he would not be making recommendations on FAA Criteria or policy.

The military has conducted some extensive tiltrotor rotorwash testing. In the tight quarters associated with shipboard operations, the Navy needs to develop procedures that protect their shipboard crews. Mr. Ferguson discussed the personnel hazard threshold testing conducted by the Navy, their application to a hovering XV-15, and the regions of overturning forces around this aircraft when hovering. Based on this, he described comparable thresholds for three categories of civilian personnel (trained ground crew personnel, adult passengers, and children).

Based on analysis of measured data, Mr. Ferguson presented graphs of overturning forces and of rotorwash velocity for the V-22 and the XV-15. Some of these graphs were plotted as a function of distance from the aircraft center (DFAC) on the 270 azimuth (left wing). Other graphs were plotted as a function of the distance along the interaction plane (DAIP) on the 0 azimuth (nose) and the 180-degree azimuth (tail). Additional data reduction will be required to define the dimensions of the regions, around the XV-15 and the V-22 during ground maneuvering, similar to the regions defined around the hovering XV-15. For the XV-15 during ground maneuvering, the dimensions of these regions are expected to be smaller than when the aircraft is hovering. For the V-22 during ground maneuvering, the dimensions of these regions are expected to be somewhat larger than the dimensions for the hovering XV-15.

The rotorwash generated by the XV-15 is comparable to that generated by the S-76. The rotorwash generated by the V-22 will be larger since it is a heavier aircraft.

Conclusions from the Flight Data Test Data:

a. Measured V-22 ground-taxi and air taxi velocity and force levels closely match those measured for the V-22 in a fixed position (for "normal" levels of pilot maneuvering aggressiveness.

b. Ground taxi of all rotorcraft significantly reduces rotorwash effects and mitigates unknowns due to pilot aggressiveness and ambient winds.

c. While rotorwash generated forces on personnel are important, other comfort factors (related to noise, blowing sand, etc.) will most likely be the combination of critical factors that determine policies/procedures that separate passengers from tiltrotors with rotors turning. (Ground crew represents a separate, less demanding consideration due to their training and protective equipment.)

3. Discussion.

Several members of the WG stated that the flight test results supported the position that they had taken many months ago. The WG discussed the issue of passenger loading bridges and the factors that would influence industry decisions on whether or not to use them at a vertiport providing scheduled services. The WG also discussed the considerations that will influence choices on vertiport operational procedures in the vicinity of the loading gates. Mr. Ferguson stated his opinion that passenger comfort issues (concern about rotorwash blowing sand or dust in the eyes of passengers or similar considerations) will place greater constraints on operational procedures than the prospects of overturning passengers since the threshold is much lower and the distances much larger.

Previous, the WG had concluded the both the V-22 and the B-609 would ground-taxi rather than air taxi during ground maneuvers. At this meeting, the WG agreed that a large, wheel-equipped helicopter (such as the S-76, the S-92, and the EH-101) would also ground-taxi rather than air taxi during ground maneuvers.

The WG briefly discussed Air Taxi Routes. The FAA is not aware that any such routes are in use in the USA. Dr. Leverton stated that the only one of which he was aware was at Boston Logan. Mr. Mowbray suggested that Tom Grassia, President of the New England Helicopter Council, would be a good Industry contact routes and procedures at Boston Logan.

4. Next Meeting.

The WG decided to hold the next meeting on Wednesday October 15 in Washington DC.
(It was subsequently shifted to October 14.)

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
June 1, 1998

Attendance

Robert Bonanni, FAA Co-Chairman
William Decker, NASA Ames
Dr. John Leverton, Industry Co-chairman
Norm Mowbray, Bell Textron
Ron Reber, Bell Textron
Bill Sanderson, HAI
Rick Simmons, NASA Ames
Robert D. Smith, FAA
Alan Todd, Bell

Minutes

1. **Co-Chairman's Remarks.** Dr. Leverton chaired the meeting. Dr. Leverton made opening remarks on the difficulties presented by the departure of Boeing from the Bell/Boeing BB-609 Team. In particular, it will make it more difficult to address the 40-passenger civil tiltrotor (CTR). Although Boeing personnel have expressed a continuing interest in this advisory circular, their interests are increasingly focusing on the military V-22 Osprey. No Boeing personnel are present at this WG meeting and it is unclear whether they will participate actively in future meetings. This increases Industry's interest in getting published the FAA technical report that is referred to as "VERTAPS". Mr. Decker concurred on this point. In particular, the VERTAPS document has some short take-off and landing (STOL) analysis that would be of interest.

A question was raised on the status of the NASA AATT document. NASA indicated that they do not intend to publish the AATT report but that they plan to publish an executive summary.

Mr. Bonanni indicated that he would like to discuss schedule of the Vertiport Design AC later in the meeting.

2. **Heliport Design AC Status.** Industry reported that they were happy with the May 22 "town hall" meeting at the American Helicopter Society International Annual Forum. Mr. Bonanni stated that the FAA was looking forward to the planned technical discussions with Industry.

3. **Homework Status.** Mr. Smith reported on his latest discussion with the FAA Rotorcraft Certification Directorate. The Directorate is optimistic that they will reach an agreement with Bell on BB-609 certification basis by late summer. When such an agreement is reached, the Directorate would be prepared to brief this Working Group on this matter. Mr. Smith suggested that the Working Group may wish to schedule their next meeting in Fort Worth with this thought in mind. However, he cautioned that group the FAA Rotorcraft Certification Directorate would not be prepared to suggest a specific briefing date until sometime in September. A discussion of the next meeting date was deferred until the end of the Working Group meeting.

Mr. Smith also commented that a recent Tiltrotor Terminal Instrument Procedures (TERPS) Working Group meeting in Oklahoma City had impressed upon him that we are dealing with a system. This system is composed of the aircraft (certification basis), the aircraft operations procedures (how it is flown), tiltrotor pilot certification and training requirements, landing site design characteristics (the Vertiport/Heliport Design AC), and TERPS (obstruction clearance airspace, procedural design rules, and weather minimums). Mr. Smith said that, while it is possible to minimize the requirements of one of the components of this system, it is not possible to minimize the requirements of all of the components without resulting in an unacceptable accident rate. Thus, it will be important for this Working Group to consider the implications inherent in the tiltrotor certification basis when agreement is reached between Bell and the FAA.

Dr. Leverton expressed a contrary opinion that the Working Group should not be delayed by the lack of agreement on tiltrotor certification basis in developing ground facility size requirements.

"Vertiport Design AC - Status of Issues Raised During WG Discussions". Mr. Smith provided copies of an update of this document. It was entitled "Status of Key Issues Raised in WG Discussions' and was dated June 1, 1998.

V-22 Performance Data. Mr. Todd provided copies of segments of the unpublished V-22 NATOPS document. He cautioned the group that, since this document has not yet been published, we should not release this material outside of the WG.

Terminal Issues/Influences of Rotorwash: Gate Requirements. Although Mr. Syms could not attend today's meeting, he provided the WG with a short paper addressing Port Authority of New York and New Jersey (PANYNJ) experience with turboprop operations at Newark Airport, Newark NJ. [The paper was entitled "Commuter Aircraft Ramp and Passenger Safety Practices, Possible Application to Tilt-Rotor Aircraft" and was dated May 27, 1998.] When propellers are turning, no passengers are allowed to board or deplane within approximately 200 feet. Mr. Smith commented that some similar operational restriction might be one possible solution to this safety concern at a vertiport. However, it does place a significant limitation on vertiport capacity. Other possible solutions would include larger separations between gates or the use of loading bridges (similar to jetways used a hub airports but designed for tiltrotors and turboprop aircraft). Several members discussed the increasing use of loading bridges for turboprop operations. Several members stated their opinions that the use of these loading bridges seems to be driven by passenger comfort concerns. Mr. Smith commented that loading and unloading of handicapped passengers may also be a factor due to the laws that have been passed recently on this topic. Both of these factors are likely to affect how vertiports are designed to handle scheduled service passengers. Mr. Smith also reminded the members that the WG has previously considered an issue paper on the topic of loading bridges.

Several WG members recommended that people read the May 18, 1998 issue of Aviation Week & Space Technology. This issue has a special report on regional airlines. [Of the five articles published, the article entitled "Regionals Building at Nation's Hubs" might be of greatest interest to this WG. It discusses the use of "tunnel bridges" for loading and deplaning passengers.]

4. **NASA Briefing on CTR Simulation Results.** Due to the expected content of the NASA briefing, the WG decided to move this item forward in the agenda. Mr. Decker briefed the WG on the results of NASA tiltrotor simulation testing on the Vertical Motion Simulator (VMS). In particular, he discussed the results of simulations of one-engine-inoperative operations and the impact on vertiport size requirements, vertiport marking and lighting, and complex approaches for noise abatement. Mr. Simmons also participated in the discussion during this presentation. Mr. Decker advised the WG that some of this material would be a repeat of things on which they had been previously briefed. However, he assured the WG that the briefing would cover a significant amount of new material.

CTR VMS Simulation. Mr. Decker outlined briefly the objectives of the various CTR VMS simulations (CTR-1 through CTR-6). He noted that CTR-4, conducted in November 1994, was a precursor to the FAA VERTAPS work. In response to a question from Mr. Reber, Mr. Decker pointed out that simulations CTR-1 through CTR-6 used the Generic Tiltrotor Simulation model configured as a 40,000 pound JVX aircraft. This model incorporates an attitude command stability and control augmentation system (SCAS) that keeps workload lower, automatic flaps, torque command and limiting system, and NASA-developed semi-automatic nacelle angle control systems.

NASA recommends NOT making changes in the approach path below 1000 feet above ground level (AGL). Earlier NASA presentations of the CTR-6 noise abatement profile showed the glide slope break as low as 500 feet. Such a low altitude was used during the CTR-6 experiment strictly to investigate how close to the landing decision such a glide slope change could be made. Results of that work fed into the current recommendation for transitioning to the final approach angle no later than 1000 feet above the landing surface. In response to a question from Mr. Smith, Mr. Decker stated that the avionics guidance sensitivities assumed for the CTR work (particularly the CTR-6 assumed GPS sensitivities) are tighter than what is in the current RTCA Minimum Operational Performance Specification (MOPS) and that he was not aware of any plans to change the MOPS. This means that the lateral dispersions seen in the NASA experiment might be tighter than what could be expected with GPS avionics that are consistent with the current RTCA MOPS.

Approach Rule of Thumb. A large volume of NASA approach flight testing in many different aircraft models has led to the recommendation that pilots should "Descend at no more than 1000 feet per minute below 1000 AGL." (reference: Scott, B.C., et al., "Progress Toward Development of Civil Airworthiness Criteria for Powered-Lift Aircraft", FAA-RD-76-100, May 1976). This rule and simple geometry lead to the constraint that the nominal ground speed of a tiltrotor 9 degree approach should be no more than 55 knots during the final phase.

OEI Considerations. In designing landing sites and approach procedures, one needs to address the possibility of OEI (One Engine Inoperative). In particular, vertiport size is dictated by operational requirements: (1) The pilot must be able to continue safe operation in the event of a major system failure. (2) One engine inoperative performance is critical for low-speed, close-to-the-ground operations. Simulation showed that, after an engine failure on approach, subjects needed the contingency engine power for about 20 seconds. After 20 seconds, the aircraft was either safely on the ground or the pilot was safely flying away and no longer needed the contingency power. Current engine rating practices (30 second and 2 minute contingency power) were mentioned.

Power Assumptions. The CTR-5 simulation investigated the impact of OEI contingency power level on terminal area operations and vertiport size. Two principal OEI power scenarios were evaluated: (1) a modest short-time contingency rating 15% above a minimum single engine continuous rating. This provided sufficient power to maintain level flight down to an airspeed of 30 knots. (2) A higher OEI short-time contingency rating 30% above the single-engine continuous rating. This provided power for level flight down to just under 20 knots and was sufficient to provide hover in ground effect up to about a 10 feet wheel-height. The case where sufficient OEI power was provided to hover out of ground effect was considered trivial and was not investigated. The minimum flight speed available during an OEI recovery was viewed as critical to the type of operations and size of facility required. Even now, it is not clear where the BB-609 will fall in this continuum but it is believed that it will fall somewhere within the range of the NASA assumptions. Using this framework, Mr. Decker discussed approach and departure strategies and he presented the results of simulation efforts under various scenarios.

Approach Simulation Results. Two approach strategies were investigated depending on the level of OEI performance: (1) With only modest OEI performance (30 knot minimum level flight speed--"15% engine" of the CTR-5 experiment), the approach features descent on flight path angles up to 9 degrees to arrive at a landing decision point, LDP, at 50 knots with 80 degrees nacelles (approximately 6 degrees below the hover setting). This flight condition provided for an easy transition to a missed approach (go-around), even with one engine inoperative. The semi-automatic (discrete) nacelle angle control system and automatic flap schedule developed by NASA contributed to an acceptable landing workload from this LDP condition. (2) A second approach strategy was investigated for scenarios with better OEI performance (e.g., less than 20 knot level flight and hover in ground effect OEI performance--the "30% contingency" engine of the CTR-5 experiment). This approach featured a constant, gentle, deceleration through the landing decision point to arrive at a hover just prior to touchdown. This approach required lower pilot workload during the critical landing phase. Final approach angles of 9 and 15 degrees were investigated with this approach and requisite OEI performance. Most of the CTR-5 approach evaluations featured a 9-degree final flight path angle. A smaller number of the approach scenarios looked at a 15-degree approach angle. In response to a question, Mr. Reber stated that Bell is not pursuing any angles steeper than 9 degrees. Three departure scenarios were investigated: (1) an airspeed-over-altitude departure which begins from a low hover, (2) an "Extremely Short Take-Off (ESTO)", rolling departure, and (3) a hover-back-up maneuver used only with the higher OEI performance (hover in ground effect OEI performance).

The baseline 9 degree approach (50 knots & 80 degrees nacelle angle at LDP) requires about 6 to 8 degrees pitch attitude at the LDP. This pitch attitude, combined with the 9 degree approach geometry (200 feet height at 1260 feet from the touch-down aim point) does not allow the pilots to see much of the approach lights under the aircraft at the LDP for expected tiltrotor windshield geometries. Since the BB-609 is expected to provide the median pilot with 16 degrees of lookdown angle, this provides a good field of view, sufficient to use this approach strategy.

NASA has investigated two-segment approaches for noise abatement. Most of this NASA noise abatement approach profile work has used a 3-degree initial approach path followed by a 6 or 9-degree final. A preliminary investigation of the reverse of this -- a steep approach angle

(9 degree) followed by a shallow approach angle (3 degrees) quickly revealed several problems. When the approach transitions from a steeper angle to a shallower angle (e.g., from 9 to 3 degrees or from 15 to 9 degrees), pilots tend to go below the shallower approach angle during the glide slope transition. Further, the steep initial segment would still require a slow approach speed (e.g. 55 knots on the 9-degree segment), further reducing any advantages such an approach might seem to provide. This type of approach would increase the TERPS airspace dramatically. Going from the shallower angle to a steeper angle does not present this difficulty. [In response to a question, Mr. Sanderson confirmed that the Navy does conduct operations where the approach transitions from a steeper angle to a shallower angle. However, they only do this over water where obstacles under the approach path are not a major consideration.]

In one part of the CTR-5 approach simulation [assuming a non-hover OEI capability], evaluation pilots made 9-degree approaches to a 600 foot long elevated deck. In roughly 80-90 percent of the approaches, the scenario involved a simulated engine failure after the pilots had made the commitment to land. With zero as the center point, pilots used from -274 feet for touchdown to +251 feet for the final stop. Pilots used the space they perceived as available (±300 feet). With one engine inoperative, pilots typically touched down with between 20 to 50 knots of forward velocity. [Engine failures were inserted between 20 and 50 knots and results were analyzed and presented in terms of failure insertion airspeeds.] Normal operations would be conducted with a vertical (hovering) touchdown.

In another part of the CTR-5 approach simulation [assuming a hover in-ground-effect OEI capability], subject pilots made 9-degree approaches to a 150 foot square ground-level pad. Again, in roughly 80-90 percent of the approaches, the scenario involved a simulated engine failure after the pilots had made the commitment to land. With zero as the center point, pilots used from -151 feet for touchdown to +176 feet for the final stop. In the OEI scenarios, pilots touched down with 10 knots to 30 knots of forward velocity.

In another part of the CTR-5 approach simulation [assuming a hover in-ground-effect OEI capability], subject pilots made 15-degree approaches to a 150 foot square ground-level pad. Again, in roughly 80-90 percent of the approaches, the scenario involved a simulated engine failure after the pilots had made the commitment to land. With zero as the center point, pilots used from -234 feet to 0 feet. Pilots touched down with 10 to 30 knots of forward velocity with one engine inoperative.

Departure Simulation Results. In the CTR-5 departure simulation [airspeed over altitude departures assuming non-hover OEI capability], it was difficult to control rejected takeoffs. The average rejected take-off stop distance was 601 feet with a high standard deviation of 251 feet. Maximum stop distance was 1505 feet. On continued take-offs with OEI, the distance to clear a 35 foot obstacle averaged 689 feet (standard deviation: 347 feet; maximum distance 1235 feet). The large dispersion (large standard deviation of rejected takeoff or 35 feet obstacle clearance) points to the difficulty expressed by pilots with the maneuver.

An alternative investigated during the CTR-5 departure simulation were extremely short take-offs (ESTO) assuming non-hover OEI capability. The average rejected ESTO take-off stop distance was 403 feet (standard deviation: 139 feet; maximum stop distance: 673 feet). On continued take-offs with OEI, the distance to clear a 35 foot obstacle averaged 940 feet (standard deviation: 495 feet; maximum distance 1543 feet). With the aircraft having never left the ground, the rejected take-offs were easier to handle, providing more consistent performance.

Hover-back-up take-offs were investigated during the CTR-5 departure simulation with an assumed hover in-ground effect OEI capability. Aircraft were operated from a simulated 150 feet square ground-level pad. With zero as the center point, pilots used from -87 feet to +27 feet during rejected take-offs. Continued OEI takeoffs were all performed from heights above 35 feet and never dropped below this height.

The Importance of Engine Power. NASA stated that the results of this CTR simulation and landing site design requirements associated are not a function of aircraft size. Rather, the primary driving factor appears to be the minimum level flight speed with OEI power. With "15 percent contingency" power (77% HOGE power) resulting in a 30 knot minimum level flight airspeed, a 600 feet paved rollway plus clearways is just adequate for landing the

CTR. With "30 percent contingency" power (87% HOGE power) resulting in less than 20 knots level flight airspeed, the CTR requires a 150 square pad for departure and a 150x200 foot pad for approach.

Marking and Lighting. NASA emphasized that marking and lighting must support the intended flight operations. Effective marking and lighting are needed to enable safe operations by the pilot who arrives at the decision point "two dots off" (maximum tolerable instrument approach tracking error). Providing the pilots with proper visual cueing is critical. One of the key issues in the CTR-5 simulation testing was the use of a large vertiport marking symbol (100 feet wide in the simulation scene - two thirds of the TLOF width which was 150 feet in the simulations) in the center of the landing surface. This allows for landing short, landing long, and for the deceleration to a stop. After discussion, the WG agreed that it is appropriate to place the vertiport marking symbol in the center of the landing surface rather than at the ends as recommended by the current Vertiport Design AC.

NASA also recommended the use of rollway heading numbers and a rollway centerline. No one in the WG objected to these recommendations. Additionally, NASA questioned whether it would be beneficial to add an additional vertiport identifier on the rollway ends. The WG agreed that there is a need to ensure that the GA fixed-wing pilot will have a STRONG visual indication that the vertiport is NOT a short runway for a fixed-wing aircraft. There was not a clear agreement on how to accomplish this.

For operations in limited visibility, NASA spoke favorably upon the use of heliport instrument lighting system (HILS) [wing lights] and the heliport approach lighting system (HALS). Wing lights help to identify that this is a vertiport and not a runway. With the approach lights, simulation results show that outbound lights are needed as much as inbound lights. Only a short segment of the HALS is visible at breakout minimums (e.g., at 1260 feet from touchdown for a 9-degree approach at a 200 foot LDP). A longer string of approach lights (1000 feet) does support operations with "slightly more than minimum" visibility. NASA also recommended that logarithmic spacing of approach lights be investigated.

Dr. Leverton expressed his concern that we have no operational experience with the HALS and that no other alternatives are currently available. In the discussion on this issue, Mr. Smith asked the group how many were familiar with the cold cathode lighting used at the NationsBank South during Heli-STAR operations and now located at the Park Police Heliport in Anacostia. [Only two members indicated that they were familiar with this lighting.] Would the unique green color of this lighting provide a strong nighttime indication that the vertiport is not a runway? The WG agreed that heliport and vertiport lighting is an area in need of review on an urgent basis. Although it would be impossible to accomplish at this late date, it would have been highly desirable to have completed this lighting research prior to the start of helicopter and tiltrotor terminal instrument procedures (TERPS) development.

Mr. Smith spoke very briefly about ongoing FAA heliport lighting research. In response to a request from Dr. Leverton, he stated that contractual constraints would not allow the FAA to provide a detailed briefing on this topic at the next WG meeting. However, there are several FAA technical reports currently in process. These are expected to be published prior to the end of the calendar year.

Mr. Smith commented that runways have different marking depending on whether they support VFR, non-precision, or precision operations. He asked the WG if we should develop something similar to this for vertiports. Messieurs. Decker and Simmons responded that centerline lighting and edge lighting would be very useful for non-precision and precision operations at a vertiport. No WG member objected to this assertion.

Visual Glideslope Lighting Systems. NASA spoke briefly about several different types of visual glideslope lighting systems. The VASI is unusable for low speed (steep angle) approaches since some of the lights disappear below the cockpit viewing angle well prior to touchdown. The PAPI is usable but not necessarily ideal for steep angle vertiport operations and it does not support operations at multiple angles.

NASA emphasized that this CTR simulation should be considered as preliminary and that detailed flight procedures have not yet been developed for the various operations tested and that the pilots have not yet been trained to these procedures. [On the other hand, pilots knew what to expect (e.g., engine failure, etc.) and were keyed to respond

quickly. In the real world, they might take longer to react.] Mr. Smith also pointed out that the facility design is intended to provide adequate space for the pilot to land even in the 6-sigma situations. The NASA simulation does not have sufficient test cases to provide an assurance that they can reach a 6-sigma reliability on this issue.

CTR Noise and Its Impact on the Choice of Approach Angle. Blade vortex interaction (BVI) is the dominant component of CTR noise during approach. Mr. Decker spoke about helicopter noise on approach and the strategies used to minimize this noise. Based on XV-15 noise measurements, CTR noise on the approach to landing will be significantly larger than on departure (unlike fixed-wing air transport aircraft). Tiltrotor aircraft are expected to be noisier on a 6 degree, 80 knot approach (a common helicopter approach--also noisy for the helicopter) than at other angles. NASA recommends that a way to minimize this noise is to use a two-angle approach. The initial portion of the approach is at 3 degrees. The CTR should transition to the final 9-degree approach at a height of about 1000 feet until touchdown. This two-angle (two-segment) approach significantly reduces the long tail of the footprint of the highest noise contours. Simulation shows that, while the two-segment approach has a somewhat higher pilot workload, the workload is acceptable.

During the discussions, Mr. Simmons commented that, if airspace is not critical and noise is not an issue, pilots would prefer a 6-degree approach since this is a very low-workload task.

Mr. Bonanni asked, "Is the current Vertiport Design AC providing good advice?" Several WG members commented that they are receiving regular requests for vertiport design guidance. Mr. Decker commented that the current document is weakest in marking and lighting. The WG agreed with this statement. There was also agreement that the vertiport identification symbol should be moved to the center. Takeoff operations will still commence from the rollway/TLOF ends. Mr. Decker recommended putting out an addendum that moves the vertiport symbol to the center and significantly increases it size. Dr. Leverton also expressed his opinion that lighting is one of the AC's weak areas. Approach lighting is an area of particular concern.

5. Vertiport Size Requirements.

Dr. Leverton reminded the WG of discussion at the July 1997 meeting when we addressed tiltrotor landing and takeoff requirements under three scenarios: (1) VTOL/STOL scenario,
(2) VTOL scenario, and (3) STOL scenario. Dr. Leverton expressed his opinion that the STOL and VTOL requirements now look the same and need not be discussed separately. No one objected to this recommendation. Based on today's NASA briefing, the WG agreed on the need for a 600 foot rollway.

Dr. Leverton led the WG in a discussion of the requirements of the minimum vertiport FATO and TLOF requirements. After discussing these matters, Industry proposed a 250x90 foot (250 feet x 1.5D) FATO and a 150x60 foot (150 feet x 1.0D) TLOF where D is the rotor-tip-to-rotor-tip width. It was recognized that the FATO must be a surface that would provide ground effect support to an aircraft on approach and departure. The NASA representatives supported this proposal. Mr. Smith expressed FAA reservations on these dimensions. He restated that vertiport design recommendations one component in a system that also includes the aircraft (certification basis), the aircraft operations procedures (how it is flown), tiltrotor pilot certification and training requirements, and TERPS (obstruction clearance airspace, procedural design rules, and weather minimums). It is possible to minimize the requirements of one of the components of this system but it is not possible to minimize the requirements of all of the components without resulting in an unacceptable accident rate. A number of these components are not yet final. Mr. Smith further added that, in the discussions of the WG, it often appears that Industry wants to minimize all requirements of all components of this system. Industry arguments tend to deal with these components one at a time. The WG must not loose sight of the need to address all of them as a system. Otherwise the accident rate is likely to be unacceptable. Dr. Leverton said he did not consider this to be the case, since Industry members were attempting to consider the total picture, including safety, while at the same time taking advantage of the unique performance/operational features of the CTR. Dr. Leverton also pointed out that the range of components highlighted by Mr. Smith are no different than those that have to be taken into account when assessing any landing and takeoff facilities including heliports.

Mr. Bonanni raised the issue of vertiport requirements for something equivalent to certain airport design requirements including runway safety area, runway protection area, safety zone, and object free area. Mr. Simmons commented that no one can argue that these areas do not need to be addressed. There will be arguments on their actual dimensions.

In considering the vertiport rollway and the minimum vertiport FATO/TLOF, Dr. Leverton commented that there would be a need to "blend" the two types of facilities. The AC must address how the design requirements transition from one case to the other. Dr. Leverton volunteered to consider how this might be done.

Mr. Bonanni commented that it would not be appropriate to "mirror" the Heliport Design AC in the Vertiport Design AC. This would do a disservice to the technology. Mr. Bonanni volunteered to draw up the areas for vertiport design parameters based on appropriate airport design requirements.

Mr. Reber announced that Bell plans to request 3, 6, and 9-degree precision approaches at a full-blown vertiport located at the Arlington Texas Airport (adjacent to Bell Plant 6).

6. <u>Tiltrotor Rotorwash</u>.

Mr. Smith briefed the group on progress in obtaining tiltrotor rotorwash data. Bell has previously provided XV-15 rotorwash data with the aircraft on the ground. (Earlier data was restricted to scenarios where the aircraft was airborne.) V-22 rotorwash data collection is complete and the FAA expects to receive copies of the results from the Navy in the next several weeks. We hope to be able to present this information to the WG at the next meeting and to get their advice on how to proceed.

Dr. Leverton asked how the data would be used and what is the basis of the threshold where the rotorwash becomes a concern. Mr. Smith responded that FAA has relied heavily on military research in this area. Military research has generally been based upon the assumption that military personnel working in a rotorwash environment are generally male, weigh at least 130 pounds, wear protective clothing, and will receive special hazard avoidance training. Military testing has established a 40-knot personnel threshold for V-22 operations onboard ship. Some civilian tiltrotor passengers will be significantly shorter and lighter than these military personnel and civilian passengers will not be trained or wearing protective clothing. On this basis, the FAA suggests that the personnel threshold for civilian passengers should be no more than 30 knots.

Dr. Leverton expressed some concern that the 30-knot threshold might be too high for civilian personnel. Mr. Smith acknowledged that this might be the case. Minimal research has been conducted to quantify what is unpleasant, uncomfortable, or dangerous to the untrained and therefore unsuspecting human (adult or child) who is either partially or fully immersed in a rotorwash flow field. Even less quantitative data exists to answer questions about what might happen to a person who is standing in or passing through such an environment while wearing a hat, carry a purse or briefcase, or leading a startled or scared child. Several years ago, the FAA developed a test plan for the purpose of better quantifying an appropriate civilian rotorwash threshold. This testing has never been conducted. In light of budget constraints, there are no plans to do so in the foreseeable future. On this topic, the FAA plans to make use of the research that has already been completed.

[Editorial note: In reviewing an FAA technical report on this topic (FAA/RD-93/31, Rotorwash Analysis Handbook, Volume I - Development and Analysis), it is clear that discussing a personnel threshold on the basis of rotorwash speed alone is overly simplistic. A more appropriate way to discuss personnel thresholds is in pounds (for force limits) or in foot-pounds (for moment limits). Mr. Smith plans to develop a white paper on this topic.]

7. <u>Vertiport Marking and Related White Papers</u>.

At a previous WG meeting, NASA had recommended the vertiport marking symbol be moved from the ends of the rollway to the center. While NASA provided some support for this recommendation, some members still had some unanswered questions on this matter. Mr. Smith commented that today's NASA briefing provided much additional information on this issue and that he found it persuasive. The WG agreed that the next revision of the AC should

recommend that vertiport marking symbol be located in the center of the rollway rather than at the ends (as recommended in the current AC).

NASA recommended that both the rollway and the FATO be marked with azimuth designations. No one objected to this proposal.

8. <u>Schedule for the Revised Vertiport Design AC</u>.

Mr. Bonanni quoted the WG's previous guidance to the FAA on the desired date for the publication of the revised AC as contained in the June 1, 1998 version of the document "Status of Key Issues Raised in WG Discussions":

> 2. Schedule. The WG has expressed a preference that the revised design AC should be published by July 1998 but that it would be acceptable if the document were published by January 1999.

At the rate that the work of the WG has been progressing, there is no chance that even the January 1999 date will be met. A significant factor in this schedule delay has been Industry's reluctance or inability to provide tiltrotor performance data. The delay in coming to a full consensus on BB-609 certification basis appears to be a factor in this reluctance. Mr. Bonanni asked the WG to reconsider their preferences on the matter of schedule. At this time, late 1999 appears to be the earliest possible publication date and even this may be optimistic. He also reminded the WG that the revision of the Vertiport Design AC would be a combined Heliport/Vertiport Design AC.

Several WG members spoke about the requests being received for vertiport design advice from individuals who are planning to build vertiports in the near future. With this in mind, Mr. Bonanni asked the WG members to consider whether the current Vertiport Design AC can remain as it is until the next revision is available or whether the current AC provides advice that is either dangerous or so significantly inappropriate that some other action should be considered. In this regard, WG members should identify specific issues in the current AC and the specific problems that they present.

9. <u>Next Meeting</u>.

Mr. Smith expressed an interest in providing a briefing on tiltrotor rotorwash data at the next meeting. Due to contractual constraints, it would be advantageous to hold this meeting no later than early September.

The WG also discussed the offer of the FAA Rotorcraft Certification Directorate to brief the members on the BB-609 certification basis on some tentative date in late September. The WG is very interested in obtaining such a briefing but, due the uncertainty of the date, decided not to schedule the next meeting in Fort Worth. The WG would be pleased to consider possible briefing dates as an agenda item during our next meeting.

The WG decided to hold the next meeting on Thursday August 27 in Washington DC.

Summary of Action Items From This WG Meeting

The WG members will reconsider their preferences on the matter of schedule for publication date of the revised Vertiport Design AC (will be a combined Heliport/Vertiport Design AC).

The WG members will consider whether the current Vertiport Design AC can remain as it is until the next revision is available or whether the current AC provides advice that is either dangerous or so significantly inappropriate that some other action should be considered. In this regard, WG members should identify specific issues in the current AC and the specific problems that they present.

Mr. Bonanni will draw up the areas for vertiport design parameters based on appropriate airport design requirements. These include vertiport requirements for something equivalent to certain airport design requirements including runway safety area, runway protection area, safety zone, and object free area.

In considering the vertiport rollway and the minimum vertiport FATO/TLOF, Dr. Leverton commented that there would be a need to "blend" the two types of facilities. The AC must address how the design requirements transition from one case to the other. **Dr. Leverton** volunteered to consider how this might be done.

Dr. Leverton will draft a letter for AHS signature expressing Industry's opinion that FAA should publish the VERTAPS report quickly so that it may be used by this WG.

Mr. Smith will coordinate with the FAA Rotorcraft Certification Directorate on a specific briefing date on the FAA/Bell agreement concerning BB-609 certification basis, perhaps sometime in late September

Outstanding Action Items from Prior Working Group Meetings

Rejected Takeoff Performance. The **manufacturers' WG representatives** have made a commitment to provide the WG with the information on rejected takeoff requirements of the CTR2000 and the BB-609. Bell and Boeing have verbally provided initial estimates of the TLOF length required for the BB-609 and the CTR2000 under certain operational scenarios. This issue should be revisited after the FAA announces its decision on certification basis and the associated rules.

Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will significantly shorten the life of the concrete surface. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BB-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material. Based on XV-15 data, Bell has provided an estimate of ground temperatures under the BB-609 exhaust. Similar data is still needed for the V-22 and the CTR2000. When it becomes available, measured data on the BB-609 would also be of great interest.

Vertiport Design Parameters. Mr. Marinelli suggested that it would be a useful exercise to design landing facilities for the BB-609 and the CTR2000 using the guidance of AC 150/5300-13, Airport Design. Mr. Berry suggested that it would be useful to look at ICAO Annex 14 dimensions. After WG discussion on this issue, Mr. Marinelli indicated that **Mr. Bonanni** would write a white paper on this topic for consideration at the next WG meeting.

Airspace Issues. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. **The manufacturers need to provide** the WG with CTR departure profiles. There was not a specific volunteer for this action item.

Safety Zones/Clearances for FATO. Mr. Marinelli volunteered that **Mr. Bonanni** would draft a white paper on this issue. **Dr. Leverton** volunteered to discuss the overrun issue with Bell and Boeing.

Taxiway Width/Parking Clearances. **Mr. Heneault** volunteered to provide Canadian criteria developed for helicopters, suggesting that they might be applicable to CTR.

Document Availability. **Mr. Wilkins** volunteered to pursue whether CTR Missions and Applications Phase II study could be made available to the entire WG. Currently, this was a proprietary document, available only to Government agencies and the manufacturers.

Document Availability. **Mr. Todd** volunteered to obtain copies of the full 1982 Bell report RW-54R-82.

White Paper on Vertiport Design Parameters. **Mr. Bonanni** volunteered to write a paper addressing specific design issues for vertiports on airports using FAA AC150/5300-13, Airport Design, as a basis. Among the issues he intends to address are overrun area, radii of runway and taxiway intersections, runway protection zone, and obstacle free zone.

STATUS OF KEY ISSUES RAISED IN WG DISCUSSIONS

June 1, 1998

1. Tiltrotor Aircraft to be Addressed in Design Guidance. The WG agreed that the following aircraft should be addressed.

a. 40-passenger CTR

b. 9-passenger CTR

c. V-22 Osprey (While it is understood that the V-22 will not be landing at civil vertiports in great numbers, such landings will take place and the vertiport ought to be designed with this in mind. It is also understood that, if a vertiport is not designed to accommodate the 40-passenger CTR, it will not be necessary to design the facility to accommodate the V-22.)

2. Schedule. The WG has expressed a preference that the revised design AC should be published by July 1998 but that it would be acceptable if the document were published by January 1999.

3. Gate Separation Requirements. The WG agreed with the following approaches:

a. use the XV-15 data to estimate the magnitude of BB-609 rotorwash using the ROTORWASH model.

b. use the V-22 data to estimate the magnitude of CTR2000 rotorwash using the ROTORWASH model.

c. use these estimates, coupled with a civilian rotorwash threshold, to define separation criteria for the protection of passengers exposed to rotorwash at vertiports under the following scenarios:

(1) Operations at adjacent gates are unconstrained and enclosed jetways/loading bridges are not used. Separations between gates are intended to protect passengers from rotorwash during loading and unloading at one gate while a second CTR is entering or departing an adjacent gate.

(2) Operations are somewhat constrained and enclosed jetways/loading bridges are not used. "Operations are somewhat constrained" means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. However, the CTR at the adjacent gate may have rotor's turning. This application would be appropriate when vertiport capacity is not a critical issue. (This case could be ignored if we are certain that rotors will NOT continue turning while at the gate.)

(3) Operations are constrained and enclosed jetways/loading bridges are not used. ("Operations are constrained " means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. In addition, the CTR at the adjacent gate will NOT have rotor's turning.)

(4) Enclosed jetways/loading bridges are used. Passenger protection from rotorwash will be provided by the loading bridge. Separations will be determined on the basis of tip clearance requirements.

At a vertiport, minimum gate separation requirements will depend on how CTR operations are conducted. The AC should define these requirements as a function of the different operations and leave the site-by-site choice from these various options to industry.

4. GPS Approach and Departure Airspace. The WG agreed to do the following:

a. Develop guidance on vertiport nonprecision approach airspace based on FAA Order 8260.42, Helicopter Nonprecision Approach Criteria Utilizing the GPS.

b. Develop guidance on vertiport precision approach airspace based on heliport MLS TERPS.

c. Make use of CAT 1 GPS TERPS if they become available prior to the finalization of the revised Heliport/Vertiport Design AC.

5. Approach and Departure Airspace. The WG will continue to address approach and departure requirements separately. As the understanding of CTR capabilities and operating procedures grows in maturity, it is likely that the WG's consensus on the minimum requirements will change. For clarity, it would be better to keep the various scenarios separate until a much fuller understanding of all the issues involved in approach and departure requirements be amalgamated into a smaller number of cases as appropriate.

6. Ground-taxi Versus Hover-taxi. The WG agreed that vertiport design guidance should be developed on the assumption that no tiltrotor will air-taxi or hover-taxi at a vertiport and that this assumption should be stated in the AC.

7. Land-use Planning Issues. The revised Heliport/Vertiport Design AC will reference FAA Order 5050.4A, Airport Environmental Handbook. The Heliport/Vertiport Design AC will address the following topics:

a. The need to integrate vertiports (and heliports) into metropolitan transportation planning per the Interstate Surface Transportation Efficiency Act (ISTEA) or its replacement

b. Noise contours and noise abatement.

8. Noise Contours. The WG agreed with the following:

a. With the 40-passenger CTR, the WG will follow the lead of the CTRDAC and use the material that they have published.

b. With the 9-passenger CTR, the WG will develop a noise contour for two operations per day and a table showing how the size of this footprint increases as the average daily number of flight operations increases.

9. Rejected Takeoff Area/FATO Protection Zone. The WG agreed that we will use the results of the NASA research and compare it with the results of the Civil Tiltrotor Development Advisory Committee (CTRDAC) deliberations. NASA recommends a paved FATO not less than 600 feet in length. For rejected takeoff, NASA results indicate a need for a safer area between 1200 and 2000 feet long.

10. Vertiport Capacity. The WG agreed to reference sections of AC150/5360-9, Planning and Design of Airport Terminal Building Facilities at Nonhub Locations, and AC150/5360-13, Planning and Design Guidelines for Airport Terminal facilities. With capacity issues that are not addressed in any ACs, such a number of gates required and how to optimize vertiport capacity, the Heliport/Vertiport Design AC should state requirements in broad terms since the subject matter will not have reached a maturity that would justify very specific guidance. It is understood that the FAA plans to combine these two AC's.

11. Vertiport IFR Approach Operations. The WG agreed that we will use the results of the NASA research. The tiltrotor approach to a vertiport will be a variable approach angle (starting at 3 degrees and completing a rapid transition to 9 degrees by the time the aircraft reaches a point 1000 feet above the landing site).

12. Vertiport Marking Symbol. The WG agreed that:

a. the "broken wheel" should be retained as the standard vertiport marking symbol,

b. its size should be two thirds of the FATO width with a minimum dimension to be decided after further deliberations on the issue of FATO width, and

c. the symbol should be in the middle of the FATO. (This is a change in the situation of an extended FATO since the current AC guidance recommends a marking symbol at each end of the extended FATO.

13. Vertiport Pavement Issues. The WG agreed that vertiport pavement issues will be addressed in FAA AC150/5320-6, Airport Pavement Design and Evaluation. This AC will be referenced in the revised Heliport/Vertiport Design AC.

14. Tiltrotor Performance Model. At one point, industry has raised questions about the NASA tiltrotor simulation model. After discussions between Bell, Boeing, and NASA, it has become apparent that there are no significant differences between the NASA and industry simulation models.

15. Protected Area. A protected area is needed on both sides of the TLOF in case an aircraft goes scurrying off the side. A protected area is also needed to provide protection in case an aircraft runs off the end of the TLOF. The WG has discussed whether "protected areas" mean "no obstacles" or whether it means that an aircraft can actually go into the protected area. The WG understands the terms "protected area" to mean that aircraft can actually go into such an area without significant damage to either the aircraft or to other property. This means that there are no obstacles in the protected area. It also means that the protected precludes any use of activity that would result in significant damage to the aircraft or other property if the aircraft were to make an rejected takeoff or an emergency landing in the protected area.

16. Terminology - Rollway. In referring to the landing and takeoff area in the STOL scenario, the WG has discussed the relative merits of the terms TLOF, extended TLOF, elongated TLOF, runway, and rollway. The CTRDAC struggled with this same concept before settling on the term "rollway". In the STOL scenario, the WG has tentatively agreed to use the term "rollway".

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP (WG)
Working Group Minutes
November 18, 1997

Attendance

Robert Bonanni, FAA Chairman
Guy Heneault, Transport Canada
Dr. John Leverton, Industry Co-chairman
Norm Mowbray, Bell Textron
Bill Sanderson, HAI
Rick Simmons, NASA Ames
Robert D. Smith, FAA
Alan Todd, Bell
Ryan Wilkins, Boeing Helicopter

Minutes

1. Introduction Co-Chairman's Remarks. Mr. Bonanni (FAA) chaired the meeting. Both Mr. Bonanni and Dr. Leverton made opening remarks.

2. Revision of the Heliport AC. The FAA has responded in writing to specific key issues raised by HAI and AHS on the draft revision of the Heliport Design AC. This letter requests that HAI/AHS provide a written explanation of their own position on these issues. A meeting date to discuss/resolve these issues has not yet been determined but was tentatively planned for mid-January.

3. Homework Status.

(a) **Status Report on Certification Standards for the BB-609.** Mr. Smith reported on his latest discussion with the FAA Rotorcraft Certification Directorate. This topic has been the subject of discussions between the FAA and Bell/Boeing for about 21 months. Bell had requested Transport Category certification because they wished to avoid the connotations associated with a Normal Category certification. After these many months of discussions, it appears that both parties have concluded that the BB-609 can not meet the requirements for Transport Category certification. Bell still wishes to avoid the connotations associated with a Normal Category certification. Thus, they have requested a Special Category certification. This request is based on the idea that, while the BB-609 does not meet the Transport Category certification requirements, it significantly exceeds the Normal Category certification requirements. The FAA has indicated that it is receptive to this request. A full written statement of the certification basis is expected to be available by early February. This latest Bell letter includes a request for certification of "guaranteed performance" and "not-guaranteed performance" rather than Category A and Category B performance.

During WG discussion on this issue, the subject of a low airspeed sensor was raised. Members discussed the benefits of having such a device on a CTR. Dr. Leverton commented that Westland had considered using the Pacer low airspeed sensor (equipment used on several military helicopters) but concluded that it would not meet the integrity requirements for civil certification. Mr. Todd stated that the BB-609 would not have a low airspeed sensor. Another member asked the question, "At a vertiport with only one approach/departure path, what do you do in a BB-609 if you have a tailwind?" What vertiport design guidance is appropriate for such a contingency?

(b) **CTR Departure Profiles and Rejected Takeoff Performance.** Mr. Todd of Bell provided the results of some XV-15 flight tests as an estimate of BB-609 performance. These data were an excerpt from a 1982 Bell report RW-54R-82. These data show observed takeoff distance as a function of rotor mast torque, nacelle angle, and wind. Mr. Simmons stated his opinion that the deceleration distance associated with an aborted takeoff would be comparable to this takeoff distance or a little longer. Several member commented that pilot response time would have to be considered and that the FAA could be expected to specify the minimum response time to be assumed as part of the certification. Mr. Simmons suggested that, during departure, a Go/No-Go decision would be made at a point on the rollway that was roughly half of the takeoff distance.

The FAA requested that Bell provide the entire RW-54R-82 report. Mr. Todd stated that he would try to obtain a copy. Several members suggested that the V-22 NATOPS manual would also be of use to the WG. Mr. Wilkins stated that he was involved in writing the current V-22 NATOPS manual. A revision of this document is expected shortly, perhaps as soon as December 1997. The revision may provide additional information on take-off performance. Mr. Todd will also attempt to provide a copy of the V-22 NATOPS manual.

Mr. Bonanni stated that the Vertiport Design AC needs to address the requirements of the CTR as it will be operated. Mr. Simmons of NASA voiced his opinion that the AC needs to address the question of a balanced field length. Mr. Bonanni stated that the current Vertiport Design AC does not have a good structure for addressing these types of issues. He looks to the Airport Design AC (AC150/5300-13) as providing a better structure and plans on using that AC as the template for the next version of the Vertiport AC.

Boeing Helicopter did not provide any data on the CTR2000. Mr. Wilkins stated that Boeing does not wish to provide any "rough-order-of-magnitude" data on anything. Based on their past experience, they prefer to wait until precise data are available. This presents the Working Group (WG) with a dilemma. It had been previously agreed that the revised AC would address the 40-passenger CTR2000 as well as the 9-passenger CTR (BB609). Mr. Smith commented that what has been learned in the last seven years clearly indicates that a revision of the existing AC material is needed. For this purpose, "rough-order-of-magnitude" data, used in concert with good judgment, would be adequate. This was discussed in general terms and it was agreed that the revision of the AC would be inhibited if Boeing continues to take the position that it would not provide such data.

(c) **Vertiport Pavement (and pavement joint) Material - Tolerance to Engine Exhausts.** Mr. Todd of Bell provided a written <u>estimate</u> of maximum ground temperatures under the exhaust of a BB-609. On a 100-degree (F) ambient day, Bell <u>estimates</u> that the maximum ground temperature would be approximately 150 degrees during ground idle and approximately 370 degrees during lift off. These data, showing maximum ground temperature as a function of rotor torque, were provided as an attachment to a August 19 Bell letter from John P. Magee to S. Fitzgerald.

(d) **Canadian Heliport Safety Zones/Clearances.** Mr. Heneault stated that he had not yet written this paper but that he would try to have it ready prior to the next WG meeting.

(e) **Tiltrotor Performance Model.** After discussions between Bell, Boeing, and NASA, it has become apparent that there are no significant differences of opinion on this topic. Thus, this issue is closed.

(f) **Vertiport IFR Approach Profile.** While Mr. Decker could not attend today's meeting, he sent a short paper entitled "CTR Steep Approach Profile for Noise Abatement" dated November 17, 1997. It was distributed to the WG members and Mr. Bonanni proposed that this topic be discussed at the next meeting. The members agreed with this proposal.

Mr. Simmons commented that, during the CTR VMS simulations, subject pilots preferred a constant-deceleration approach to a vertiport. However, in the event of an engine-out during approach, pilots using a constant-deceleration approach may land short of the pavement under some wind conditions. Thus, the NASA efforts have looked for an alternative approach that provides a higher safety margin while still meeting other requirements (small noise footprint, low pilot workload, etc.) Mr. Simmons invited the WG members to come to NASA Ames in early December to see the VMS CTR7 simulation.

Several WG members expressed their disappointment that the FAA has not yet published the results of the Agency's work on instrument approach and departures (the "VERTAPS" report). Mr. Smith agreed to see if this document could be issued to the Working Group in the near future.

Concerning the CTR work done in the Vertical Motion Simulator (VMS) at NASA Ames, Mr. Decker also provided three short American Helicopter Society (AHS) papers and one set of briefing slides. All four documents address the results of some of the early CTR VMS simulations. Since these are the only published results, the WG agreed to discuss these documents at a future meeting. The three AHS papers are titled:

"Piloted Simulator Investigations of a Civil Tilt-Rotor Aircraft on Steep Instrument Approaches", (presented at the AHS 48th Annual Forum, Washington DC, June 1992)

"Evaluation of Two Cockpit Display Concepts for Civil Tiltrotor Instrument Operations on Steep Approaches", (presented at the AHS Piloting Vertical Flight Aircraft: A Conference on Flying Qualities and Human Factors, San Francisco CA, Jan. 1993) and

"VMS Simulation of a Variable Diameter Tiltrotor", (presented at he AHS 53rd Annual Forum, Virginia Beach VA, April 29-May 1, 1997).

The briefing was presented to the Advisory Group for Aerospace Research & Development (AGARD) in May 1995 (paper number AGARD-CP-577). It is titled:

"Flight Simulation- Where are the Challenges?"

(g) **Vertiport Design Parameters.** Mr. Bonanni stated that he had not yet written a paper on this topic. At this point, Mr. Bonanni stated his belief that the Working group does not yet know enough about the CTR and its operation to write this paper.

Dr. Leverton suggested that we should develop an updated summary of the status of WG discussions. Mr. Smith called the WG's attention to the July 21, 1997 document entitled "Vertiport Design AC - Status of Issues Raised During WG Discussions". This document was distributed at the last WG meeting. Mr. Smith volunteered to update this document for the next WG meeting.

In response to a question from the FAA, Mr. Wilkins stated that the growth version of the BB-609 is likely to be a 12 or 14 person vehicle rather than a 19-person vehicle. He also commented that the CTR Missions and Applications Phase II study would be of great value to the WG. Dr. Leverton agreed but pointed out that, except for the summary, this was a proprietary document, available only to Government agencies. Mr. Wilkins volunteered to pursue whether this document could be made available to the entire WG.

(h) **Terminal Issues/Influences of Rotorwash: Gate Separation Requirements.** Mr. Syms was not present and had not provided a written report prior to the meeting. Mr. Sanderson reported that Mr. Syms had contacted him and reported that the New York Port Authorities had indicated that there was no propeller wash problems with single gate turbo-prop aircraft operations and that multi-gate turbo-prop operations were similarly acceptable provided that passenger control procedures established to ensure that propeller wake does not create a problem were followed.

Mr. Todd of Bell provided estimates of BB-609 rotorwash. These data were provided as an attachment to a August 19 Bell letter from John P. Magee to S. Fitzgerald. This attachment was titled M609 Tiltrotor - Outwash Flowfield Predictions and was dated August 18, 1997.

Mr. Smith spoke briefly about the FAA's work on this topic during the last eight years. The FAA has funded the development of a rotorwash model based on all available helicopter, tiltrotor, and tiltwing rotorwash data. The Agency's intentions are to supplement this work with additional rotorwash XV-15 data collected by Bell at the FAA's request and with V-22 rotorwash data to be collected at Pax River (if it is available in time). (Both of these sets of rotorwash data are for ground taxi operations.) At a vertiport, minimum gate separation requirements will depend on how CTR operations are conducted. The AC should define these requirements as a function of the different operations and leave the site-by-site choice from these various options to industry.

4. <u>Vertiport: Basic Dimensions</u>. During a discussion of landing requirements, Mr. Todd suggested that the CTR would be able to decelerate using both breaking and a 5 degree reversed nacelle angle. Mr. Simmons voiced his

opinion that it was not clear that a CTR pilot would be able to use both full breaking and a full 5 degree reverse nacelle angle for this purpose. Dr. Leverton commented that, for helicopters, the CAA does not allow the assumption of 100 percent use of two methods for deceleration. This raised the question of what the FAA would allow for the CTR both during approach and landing and during a rejected takeoff. In view of the expected FAA decisions on BB-609 certification, the WG expressed an interest in a presentation from the FAA Rotorcraft Directorate at the next WG meeting.

Discussion among the members raised the possibility that CTR approach and landing requirements could be more demanding, from a vertiport design perspective, than departure requirements. Some members saw this as a departure from previous discussions. Looking at the different scenarios suggested at the last meeting, Dr. Leverton suggested that the WG should continue to address the various requirements separately. For example, the WG should continue to address approach and departure requirements separately. As the understanding of CTR capabilities and operating procedures grows in maturity, it is likely that the WG's consensus on the minimum requirements will change. For clarity, it would be better to keep the various scenarios separate until a much fuller understanding of all the issues involved in approach and departure requirements in all the various scenarios involved are reached. Only at that point should these requirements be amalgamated into a smaller number of cases as appropriate. Several members voiced their support for this position and no one voiced any opposition.

Mr. Wilkins stated his opinion that defining landing distance requirements would probably be more difficult than defining takeoff distance requirements. He commented that it is likely to be somewhat difficult to define rejected takeoff area (RTOA) requirements.

Mr. Bonanni stated that the Vertiport Design AC needs to address the requirement for a CTR landing at maximum gross weight, recognizing that this represents an emergency situation. The FAA recommends a similar design requirement for airports. Thus, such a vertiport design recommendation is also appropriate. For a specific emergency at a given location, one can construct a scenario where a CTR pilot might choose to land on a nearby airport runway rather than return to the vertiport. Still, vertiport design should be such that, in an emergency immediately after departure, the pilot can safely choose to return to the vertiport and land. The only exception to this case might be the vertiport located at an airport. In this case, the pilot would presumably have the option of landing on a runway at the airport on which the vertiport is located.

5. <u>Tip Clearances</u>. In response to a question from Dr. Leverton, the FAA stated that it viewed the tip clearances proposed in the draft Heliport Design AC as an appropriate starting point for the Vertiport Design AC.

The WG discussed the relative risk associated with a 747 wing tip strike versus a tiltrotor rotor tip strike. Some members argued that the 747 wing tip strike was more of an issue due to the large weight of the aircraft. Other members argued that the tiltrotor rotor tip strike was more of an issue because of the very high speed involved.

6. <u>Vertiports on Airports</u>. Mr. Wilkins stated that Boeing has concluded that the CTR offers great potential for increasing airport capacity and that airport congestion and delay will lead others to this same conclusion. In this regard, Boeing sees great benefits to be gained from the location of a vertiport on major airports.

Mr. Bonanni volunteered to write a paper addressing specific design issues for vertiports on airports using FAA AC150/5300-13, Airport Design, as a basis.

7. <u>Discussion of White Papers on Vertiport Markings</u>. Mr. Wilkins stated his concern that moving the standard vertiport marking symbol to the middle of the rollway would result in a need for a longer landing area. Mr. Simmons stated his concern that a failure to move the vertiport marking symbol to the center would result in an off-pavement landing when a pilot experienced an engine failure after the landing decision point. He also commented that, if the approach is two dots low, the CTR will land 200 feet short. The need for a safety margin dictates that one ought to be able to complete a safe approach even if the approach is made a little bit high, a little bit low, a little bit fast, or a little bit slow. Tolerating this variability (in pilot procedures, wind conditions, etc.) dictates larger ground facilities. Very little time was available to discuss this topic in detail. Mr. Simmons invited Mr. Wilkins to fly the VMS in December so that he could come to a first hand understanding of this issue.

In a related discussion, Mr. Wilkins stated his opinion that the marking of a vertiport on a stub runway should be different from the marking of a stand-alone vertiport.

8. Other Issues. Mr. Bonanni requested that WG members provide him with agenda items for the next meeting. Several members expressed an interest in having the FAA Rotorcraft Directorate brief us at the next meeting. Mr. Smith volunteered to contact them in this regard. Mr. Wilkins and Mr. Smith both expressed an interest in discussion vertiport marking at the next meeting.

9. Next Meeting. The WG discussed holding the next meeting in early March 1998. In view of the expected FAA decisions on BB-609 certification criteria, several WG members suggested that it would be profitable to have this meeting in Fort Worth TX. The WG discussed the possibility of holding the meeting over two days with half of the meeting in the afternoon of the first day and half of the meeting on the morning of the second day. In so doing, it would mean one night's lodging instead of two. It would also allow more time for discussion than what would be possible in a single-day meeting. Mr. Todd volunteered to ascertain if Bell could host all or part of the WG meeting at a Bell facility in the Fort Worth area. Mr. Smith volunteered to contact the FAA Rotorcraft Directorate about holding all or part of the next WG meeting at the FAA Southwest Regional Headquarters in Fort Worth.

(Subsequently, it was decided that the next meeting would be held in Washington DC.)

Summary of Action Items From This WG Meeting

"Vertiport Design AC - Status of Issues Raised During WG Discussions". Mr. Smith volunteered to update this document for the next WG meeting.

Document Availability. Mr. Wilkins volunteered to pursue whether CTR Missions and Applications Phase II study could be made available to the entire WG. Currently, this was a proprietary document, available only to Government agencies and the manufacturers.

Document Availability. Mr. Todd volunteered to obtain copies of the V-22 NATOPS document for use by the WG.

Document Availability. Mr. Todd volunteered to obtain copies of the full 1982 Bell report RW-54R-82.

White Paper on Vertiport Design Parameters. Mr. Bonanni volunteered to write a paper addressing specific design issues for vertiports on airports using FAA AC150/5300-13, Airport Design, as a basis. Among the issues he intends to address are overrun area, radii of runway and taxiway intersections, runway protection zone, and obstacle free zone.

Location for the Next Meeting. Mr. Todd volunteered to coordinate Bell's response regarding the possibility of holding all or part of the next WG meeting at a Bell facility in the Fort Worth area. Mr. Smith volunteered to coordinated with the FAA Rotorcraft Directorate about holding all or part of the next WG meeting at the FAA Southwest Regional Headquarters.

Agenda Items for the Next Meeting. Several members expressed an interest in having the FAA Rotorcraft Directorate brief us at the next meeting. Mr. Smith volunteered to contact them in this regard.

Outstanding Action Items from Prior Working Group Meetings

Rejected Takeoff Performance. The manufacturers' WG representatives have made a commitment to provide the WG with the information on rejected takeoff requirements of the CTR2000 and the BB-609. Bell and Boeing have verbally provided initial estimates of the TLOF length required for the BB-609 and the CTR2000 under certain operational scenarios. This issue should be revisited after the FAA announces its decision on certification basis and the associated rules.

Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will significantly shorten the life of the concrete surface. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BB-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material. Based on XV-15 data, Bell has provided an estimate of ground temperatures under the BB-609 exhaust. Similar data is still needed for the V-22 and the CTR2000. When it becomes available, measured data on the BB-609 would also be of great interest.

Vertiport Design Parameters Mr. Marinelli suggested that it would be a useful exercise to design landing facilities for the BB-609 and the CTR2000 using the guidance of AC 150/5300-13, Airport Design. Mr. Berry suggested that it would be useful to look at ICAO Annex 14 dimensions. After WG discussion on this issue, Mr. Marinelli indicated that **Mr. Bonanni** would write a white paper on this topic for consideration at the next WG meeting.

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Terminal Issues/Influences of Rotorwash: Gate Requirements. The WG discussed very briefly some of the efforts underway to acquire and analyze the data needed to come to a conclusion on this matter. One WG member suggested that PANYNJ experience with turboprop operations might shed some useful light on this matter. **Mr. Syms** volunteered to pursue this issue with the Port Authority of New York and New Jersey (PANYNJ). While some initial feedback has been provided verbally, a detailed written report/white paper has not yet been provided.

Safety Zones/Clearances for FATO. Mr. Marinelli volunteered that **Mr. Bonanni** would draft a white paper on this issue. **Dr. Leverton** volunteered to discuss the overrun issue with Bell and Boeing.

Taxiway Width/Parking Clearances. **Mr. Heneault** volunteered to provide Canadian criteria developed for helicopters, suggesting that they might be applicable to CTR.

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP
Working Group Minutes
July 22, 1997

Attendance

Vaughan Askue, Sikorsky	Deborah Peisen, SAIC
Norm Berry, Transport Canada	Bill Sanderson, HAI
Scott DiBiasio, HAI	Robert Smith, FAA
Guy Heneault, Transport Canada	Ray Syms, RA Syms & Assoc.
Dr. John Leverton, Industry Co-chairman	Alan Todd, Bell
Rick Marinelli, FAA	Peggy Wilson, Transport Canada
Norm Mowbray, Bell Textron	John Zugschwert, Textron

Minutes

1. Introduction Co-Chairman's Remarks. Dr. Leverton chaired the meeting. Mr. Bonanni (FAA) had been directed to attend a training course and could not be present. Mr. Zmroczek (Boeing Helicopter) has indicated that he will not be able to participate in working group (WG) deliberations and that Mr. Ryan Wilkins will be representing Boeing Helicopter.

Dr. Leverton commented that the agenda has been structured to offer an opportunity for the discussion of issues that have not been discussed to date.

2. Revision of the Heliport AC. Mr. Marinelli discussed two FAA concerns with the Heliport Design AC. The first is a desire to put the Heliport Design AC more in conformance with the Airport Design AC. The second issue concerns multiple standards versus one standard. The draft AC is being circulated for review within Airports. When this is complete, the draft will be available for review by the public and FAA field offices.

Dr. Leverton commented that HAI is concerned about the deletion of the private heliport chapter. HAI has the perception that the FAA is no longer working with the industry on this topic. He stated that HAI is ready to activate the Heliport Design Technical Group to review the draft AC when it becomes available.

Mr. DiBiasio asked if the draft AC would be published in the Federal Register. Mr. Marinelli responded that this was not required for an AC. Mr. Smith commented that recent administrations have strongly discouraged the publication of lengthy documents in the Federal Register. The rationale is that the total number of pages published in the Federal Register during a year is viewed by some as an indication of the burden of Federal regulations. By reducing the number of pages, it provides the politicians with a way to argue that the regulatory burden has also been reduced. Typically, instead of publishing a thick document, agencies have been publishing a short statement on the availability of a draft document and an explanation of how to obtain a copy.

Several members raised questions about the need for harmonization between FAA, Canadian, and ICAO documents on heliport design.

Mr. Todd questioned FAA about their intent to combine the Heliport Design AC and the Vertiport Design AC. Mr. Marinelli responded that this was still the FAA's intent but accomplishing this is viewed as a future task.

3. Minutes.

(a) Approval. Dr. Leverton expressed concern that the second sentence under item 3, Public versus private facilities, had been changed from what was stated at the meeting and included in the draft minutes. Mr. Smith commented that the FAA Co-chairman had directed this change because it was what had been stated in David Bennet's March 31 letter to HAI. Another WG member commented that, while the minutes state that a copy of the HAI/AHS position was attached, this was not the case. (This statement is attached to these minutes.)

(b) Matters Arising from the Minutes. Mr. Smith provided a short report on several issues.

Concerning BB-609 certification basis, Mr. Smith had agreed at the last WG meeting to discuss this further with the FAA Rotorcraft Certification Directorate (ASW). Previously, ASW had stated that they would not make a final decision on "Cat A/Cat B" certification until after they had the opportunity to gain a fuller appreciation of BB-609 capabilities through the use of a BB-609 simulator. This access is being provided during July 21-25. ASW expects to make a decision on certification basis and the associated rules by late August. Dr. Leverton commented that he understands, based on discussions with Bell and Boeing, that FAA Cat A/Cat B certification of the BB-609 is not expected. Instead, the terms "guaranteed performance" and "not guaranteed performance" are being discussed.

Concerning the briefing that Bill Decker, NASA Ames, provided at the last WG meeting, Mr. Smith distributed two white papers on related topics and suggested that the WG may wish to discuss them at a future meeting. The papers are titled "Vertiport Standard Marking Symbols" and "Vertiport TLOF Azimuth Designations". Both are dated July 22, 1997. Mr. Smith encouraged other WG members to write white papers discussing topics on which they would like to see a WG recommendation. White papers are a concise and efficient way to place information before the WG. They offer all WG members a way to reflect on these ideas away from the staccato of WG meeting discussions. White papers provide WG members with a means of conveying details and nuances that are likely to get lost if they were only conveyed verbally.

Mr. Smith also distributed a paper entitled "Status of Issues Raised During WG Discussions". He noted that it is dated yesterday so that it will be clear even months from now that it does not include the results of today's meeting. This paper is an attempt to provide a concise summary of the subjects discussed by the WG and the status of each. He suggested that this document could be revised periodically as the WG deliberations progress. The WG agreed that this would be a useful tool in support of continued deliberations.

In response to a previous question in a telephone conversation with Mr. Todd, Mr. Smith also distributed a list entitled "Documents of Interest to the Working Group" dated July 22, 1997. This list includes FAA technical reports, advisory circulars, and other documents such as the CTRDAC report to Congress and certain FAA orders.

4. Vertiport: Basic Dimensions. Dr. Leverton led the WG through a discussion of what we mean by the terms TLOF and FATO as they are used at a vertiport. At the start of this discussion, he drew several sketches of landing sites under different scenarios. These are shown in figure 1.

Mr. Smith discussed the middle and bottom sketches in figure 1 and the WG's decision to accept NASA's recommendation to place the vertiport marking symbol in the center of the extended TLOF (rollway). This works well in the middle sketch in figure 1. It presents problems in the bottom sketch of figure 1. The WG discussed the possibility of viewing the TLOF/rollway differently for approaches and departures. Several members raised issues concerning the one-way nature of the bottom sketch in figure 1. The WG recognized that a horizontal flip of this sketch would be appropriate for departures in the opposite direction. While this raises marking issues, this topic was not addressed in any detail during the meeting. As the WG discussion continued, the sketches evolved in ways that are difficult to document completely for the purpose of meeting minutes. This evolution led to the set of sketches shown in figure 2.

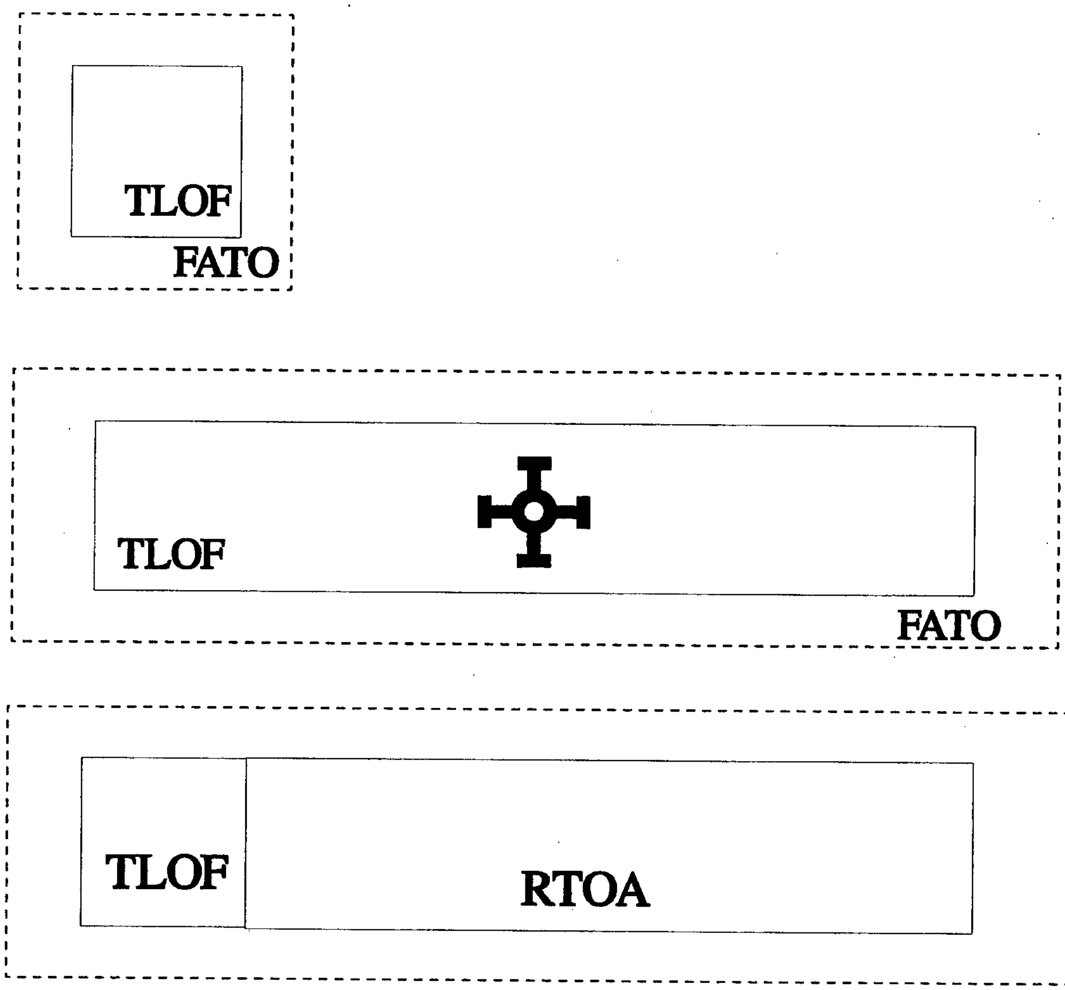

Figure 1.

FATO - Final Approach and Takeoff Area

RTOA - Rejected Takeoff Area

TLOF - Touchdown Lift-off Surface

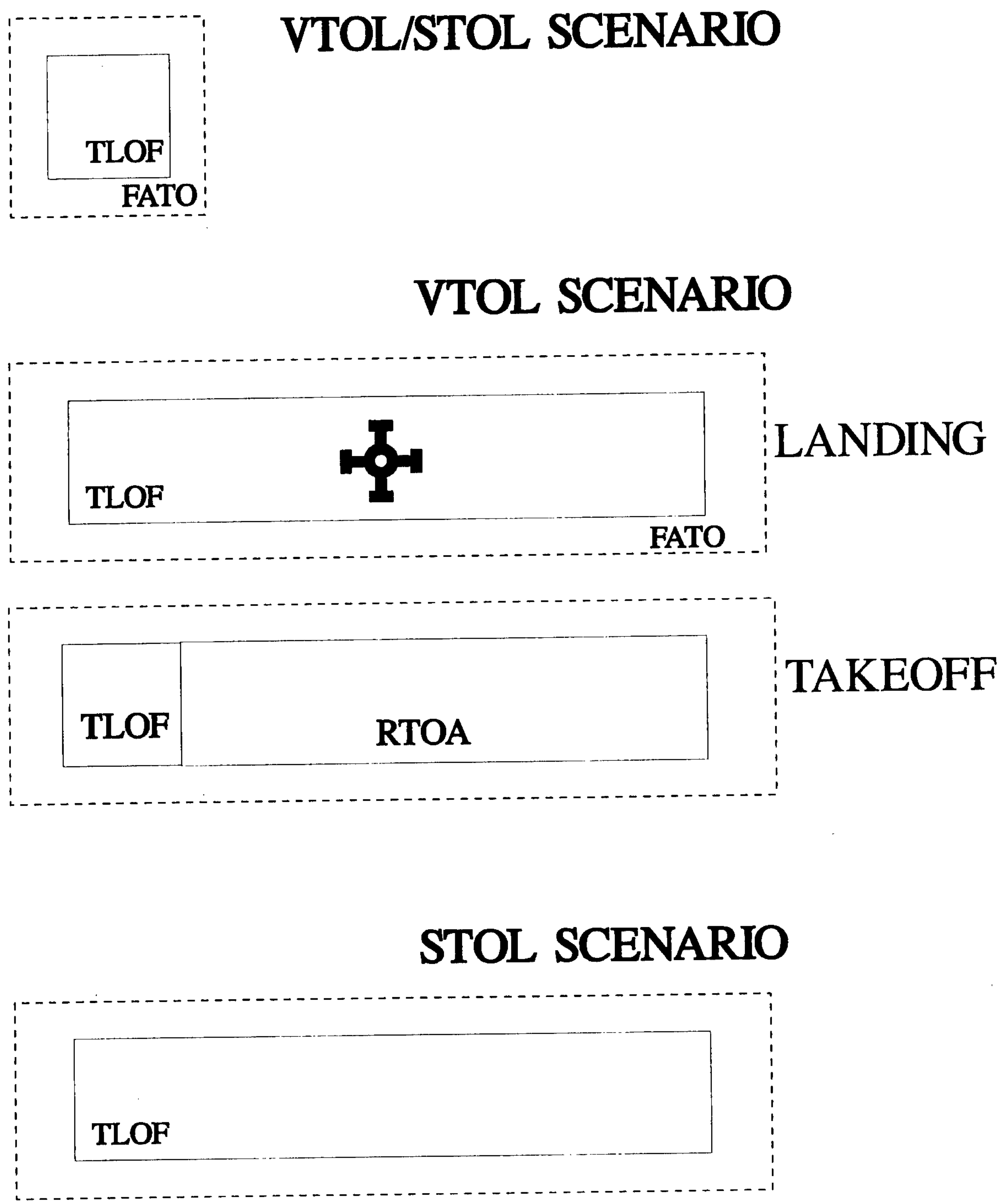
VTOL/STOL SCENARIO
TLOF
FATO
VTOL SCENARIO
TLOF
FATO
LANDING
TLOF
RTOA
TAKEOFF
STOL SCENARIO
TLOF

Figure 2.

Based on his discussions with Bell and Boeing, Dr. Leverton provided the WG with the manufacturers' estimates of the length of TLOF required by the CTR2000 and the BB-609 under various operational scenarios. He indicated that the Bell estimates were somewhat more tentative than the Boeing estimates. All of these scenarios involve the equivalent of "Cat A" operations. Dr. Leverton noted that, while "Cat A" operations provide a certain level of protection in case of an engine failure, "Cat B" operations provide no such protection.

MANUFACTURERS' RECOMMENDATIONS

Boeing Helicopter: CTR2000, "Cat A" Operations, Standard Day, Sea Level

STOL departure and rejected takeoff area: 600-800 foot TLOF required
Non-(STOL departure and rejected takeoff area): 800 foot TLOF required

Bell Helicopter: BB-609, "Cat A" Operations, Standard Day, Sea Level

STOL departure and rejected takeoff area: 500 foot TLOF required
Non-(STOL departure and rejected takeoff area): 200 foot TLOF required

In response to a question on vertical departure procedures from Mr. Smith, Dr. Leverton stated that Bell's recommendation of a 200 foot TLOF is based on initial work by Bell and NASA and assumes a vertical or backward-vertical departure similar to what used to be done during departures from the roof on the Pan Am Building in New York City. He commented that this type of "Cat A" operation was common in Europe but that few pilots in the USA had experience with it. He recommended that the WG should NOT consider the "drop-down" technique that is used on offshore rigs where the elevated helipad often allows the aircraft to drop below the level of the pad while it is gaining forward speed and the greater lift associated with this speed. The WG did not object to this recommendation.

Dr. Leverton understood that the 500-800 foot TLOFs take advantage of the breaking action available from a 5 degree backward nacelle angle of the tiltrotor rotor blades. The WG discussed how runway requirements were developed based on the assumption that the airplane's breaks have failed. A WG member commented that the rotor blades were direct-coupled and that failure of their breaking action should not be assumed. Dr. Leverton also commented that these TLOF length estimates were based on a standard day at sea level. They do not include the adjustment necessary for high temperature and high altitude.

Mr. Syms raised a question on what the CTRDAC Report to Congress had said about TLOF length. Mr. Smith responded that the CTRDAC report shows a TLOF that is 550 feet in length. In addition, he commented that, during CTRDAC deliberations, Bell and Boeing had discussed the need for a rejected takeoff distance of approximately 800 feet.

Dr. Leverton also discussed a "Cat B" vertiport with a 60 by 60 foot TLOF. The FAA made no comments on this facility.

Dr. Leverton questioned the WG on the issue of minimum TLOF width. Mr. Syms recommended that the minimum TLOF width should be 1.5 times the largest dimension of the landing gear. Another member suggested that the minimum TLOF width should be twice the width of the undercarriage. Yet another member suggested that the minimum TLOF width should be 1.5 times the tip to tip dimension of the CTR. Dr. Leverton pointed out that NASA has previously recommended a minimum TLOF width of 150 feet. Mr. Smith offered his opinion that a TLOF width of 20 feet would be grossly inadequate. As an absolute minimum TLOF width, he suggested 60 feet but stated that he was not entirely comfortable with this dimension. Mr. Marinelli commented that an application of the criteria of AC150/5300-13 (Table 3-1) would result in a TLOF width of 75 for the BB-609. (Applying the same table to the CTR2000 would result in a TLOF width of 100 feet. Both of these dimensions are based on AC150/5300-13 criteria for a runway that is either visual, i.e. VFR, or one with not lower than 3/4 mile approach visibility minimums.)

Dr. Leverton commented that, historically, larger separations have been required for IFR operations. He asked the WG how we should address this for the CTR.

Mr. Smith suggested that the WG should look at the FAA AC recommendations on airports and runways. What have airport designers learned over many decades of IFR operations? How have airport design recommendations been modified to address these lessons learned? Can we translate this into something that fits the CTR situation? Mr. Smith gave two examples of the types of issues that should be considered. In the first example, Mr. Smith suggested that the WG consider the 1000 feet overrun area at the end of a runway. While 1000 feet at the end of a vertiport rollway would probably be excessive, some fraction of that would be appropriate as a safety margin. In the second example, Mr. Smith suggested that the WG consider the issue of radii of runway and taxiway intersections. While this is a complex airport design issue, it is likely to be a simpler issue for vertiport design.

Mr. Syms raised a question on whether hydroplaning would be an issue at a vertiport. There was no WG discussion on this question.

Mr. Marinelli raised the question of whether a vertiport-specific beacon is required. Several WG members responded that the current vertiport design AC recommends that use of the heliport beacon at a vertiport. The WG did not discuss whether this recommendation should be reconsidered.

5. STOL/VTOL: Differences to be Considered. Dr. Leverton led the WG through a discussion of STOL and VTOL requirements in order to identify any issues that might need to be addressed. Mr. Berry suggested that an obstacle limitation surface (OLS) area is needed on each end of the TLOF. In addition, Mr. Berry suggested that a protected area was needed on both sides of the TLOF in case an aircraft goes scurrying off the side. Mr. Syms suggested that there is a need to provide protection in case an aircraft runs off the end of the TLOF. Mr. Askue raised a question whether "protected areas" mean "no obstacles" or whether it means that an aircraft can actually go into the protected area. The discussion in response to this question indicated that the WG understands the term "protected area" to mean that the aircraft can actually go into such an area without significant damage to either the aircraft or to other property.

Dr. Leverton suggested that, for STOL facilities, it may be better to use airport terminology such as the term "runway protection area". This led to a spirited discussion of the relative merits of the terms TLOF, extended TLOF, elongated TLOF, runway, and rollway. Mr. Smith noted that the CTRDAC had struggled with this same concept before settling on the term "rollway". Mr. Syms proposed that the WG use the term "extended TLOF". A consensus could not be reached on his recommendation. Dr. Leverton proposed that the WG adopt the term "rollway" as the CTRDAC has done. Mr. Syms withdrew his previous proposal and the WG did not object to Dr. Leverton's proposal.

6. Vertiports on Airports. Dr. Leverton asked the WG to consider if there are any special issues that need to be considered when a vertiport is located on an airport. Mr. Marinelli suggested that vertiport marking would be an issue. He noted the need to mark the vertiport in a way that does not lead to the confusion of fixed-wing pilots.

Mr. Smith suggested that there are at least three additional issues of interest: separation between a TLOF/rollway and a runway for VFR operations, separation between a TLOF/rollway and a runway for simultaneous IFR operations, and separations to address wake vortex issues.

Mr. Askue suggested that taxiway separations would be an issue.

7. VFR/IFR Implications on Size. Dr. Leverton commented that, historically, larger dimensions have been required for IFR operations than for VFR operations. How should we address this for the CTR? In response, Mr. Smith recommended that the WG look at the runway situation. With many decades of precision operations at runways, the aviation community has learned a lot based on their experiences. This has gradually been translated into airport design requirements. Specifically what have they learned? Specifically how has this been addressed in airport design requirements? How should we now translate this experience into requirements that would be appropriate for vertiport operations? Mr. Smith urged the WG to consider how airport design requirements have grown as the

industry matured with experience. Many older airports do not currently meet all airport design requirements. They may be forced to operate under a deviation because they are land-locked. They may not be able to buy the additional land needed to satisfy a specific design requirement for any amount of money. If the WG does its homework properly, we can learn from the huge body of precision and nonprecision operational experience at airports and avoid many future vertiport problems. By starting with proper vertiport design guidance before any vertiports are built, the industry can avoid many expensive vertiport upgrades later on.

Mr. Smith raised the issue on who in FAA or the airport design community would be able to address the questions he had raised. Mr. Marinelli responded that the FAA could answer these questions although he acknowledged that Airports has lost a lot of corporate knowledge during the last three years. As to industry sources, the people who do this type of design work use FAA design recommendations. However, they generally do not have an understanding of the history that has led to a particular design requirement.

Mr. Marinelli suggested that it would be a useful exercise to design landing facilities for the BB-609 and the CTR2000 using the guidance of AC 150/5300-13, Airport Design. Mr. Berry suggested that it would be useful to look at ICAO Annex 14 dimensions. After WG discussion on this issue, Mr. Marinelli indicated that Mr. Bonanni would write a white paper on this topic for consideration at the next WG meeting.

8. <u>Safety Zones/Clearances for FATO</u>. Dr. Leverton led the WG through a discussion of safety areas around a rollway. He drew the figure shown below (and labeled figure 3) and asked the WG to comment on the purpose of the protection areas represented by the dimensions a, b, and c.

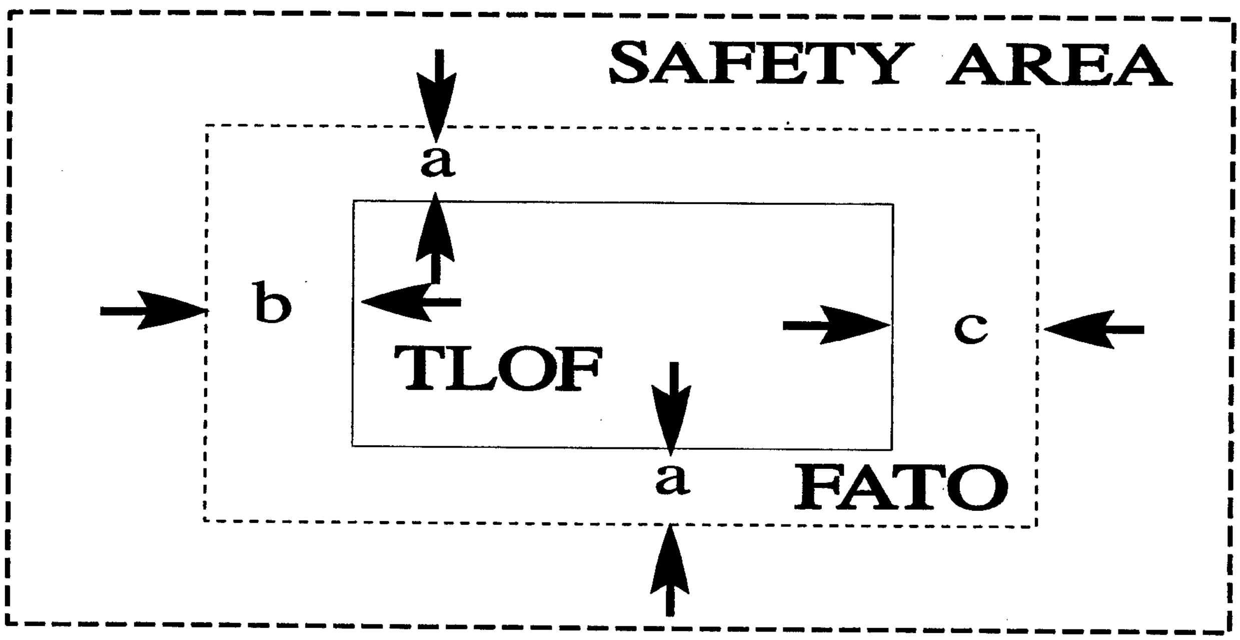

Figure 3

One WG member suggested that the dimension "a" was intended to account for an off-center landing. Another WG member suggested that it was intended to provide obstacle clearance. Several members commented that they did not know the purpose of the protection area designated by dimension "a".

During a discussion of tip clearances, Mr. Heneault raised the question of why tip clearance requirements would be different for rotorcraft with rotor diameters of 30 feet and 60 feet. Mr. Smith responded that, based on FAA testing, the tip clearance requirements would be different due the difference in the pilot's depth perception in these two situations.

In discussing the protection area designated by dimension "b", one WG member suggested that this "rollway protection area" would provide an obstacle free area. Another member suggested that it would provide an overrun area but that it would be different from the overrun area at an airport. It was noted that, when approaches take place from both directions, dimensions "b" and "c" would be the same.

Dr. Leverton recommended that the WG drop the use of the term "FATO" when discussing a rollway in favor of terms similar to those used in runway design. Some industry WG members voiced reservations on this issue. Mr. Berry recommended that the FAA look at ICAO Annex 14 dimensions. Mr. Marinelli volunteered that Mr. Bonanni would draft a white paper on this issue.

Dr. Leverton volunteered to discuss the overrun issue with Bell and Boeing.

9. <u>Taxiway Width/Parking Clearances</u>. Dr. Leverton led the WG in a discussion of considerations dealing with taxiway and parking clearances. Mr. Heneault volunteered to provide Canadian criteria developed for helicopters, suggesting that they might be applicable to CTR. Mr. Berry suggested that parking clearances need to be large enough to provide space for service vehicles.

In a discussion of taxiway requirements, Mr. Marinelli suggested that a taxiing rotorcraft should be able to move to the edge of a hard surface with no risk of hitting an obstacle. Considering such a scenario, the WG discussed the risk of starting a grass fire with engine exhaust heat if vertiport surface movements required the CTR to stop on a taxiway. The WG concluded that there is a need to preclude such a risk by facility design. The use of a stabilized shoulder was suggested for this purpose.

In a discussion of parking clearances, several WG members pointed out that it may be worthwhile to consider both the Canadian regulations and the ICAO recommendations. Mr. Syms commented that, in the "real world", rotorcraft operate with less than these clearances. Mr. Berry responded that the use of smaller clearances is allowed if other precautions are taken, such as the use of "wing walkers". Considering CTR rotorwash, another member questioned whether wing walkers would be appropriate at a vertiport.

10. <u>Vertiport Lighting</u>. Dr. Leverton asked the WG to consider what new developments can be expected to reach maturity prior to the publication of a revised vertiport design AC. Mr. Smith responded with a discussion of the opportunities and challenges that GPS will present us. Currently, we have precision approaches to about 1800 runway ends. GPS offers the opportunity to add thousands of additional runway ends as well as heliports and vertiports. While the GPS approach will be much less expensive than ILS or MLS, the required lighting has not yet received the appropriate attention. Approach light systems are expensive (capital costs, maintenance cost, and electricity costs). Neither FAA nor the airports have the money to pay for several thousand additional lighting systems that meet current standards. Industry is now developing new lighting systems that would be less expensive. However, these systems have not yet been refined, tested, and FAA-certified. Such systems offer tremendous savings to all segments of the aviation community. However, as the FAA continues to struggle with budget constraints, it is uncertain whether new lighting system technology will reach the maturity required to incorporate them in the next revision of the vertiport design AC.

Mr. Berry commented that, aside from any other safety benefits, approach light systems have been shown to reduce the percentage of missed approaches. On this basis alone, they are of value.

Mr. Smith advised the WG of what FAA Flight Standards has historically viewed as the purpose of an approach light system. PRIOR TO THE TIME WHEN THE PILOT HAS ACQUIRED THE LANDING SITE, approach lights provide the pilot with the assurance that he is approaching a landing site and they indicate whether the aircraft is on the centerline of that approach. It is on this basis that the FAA provides an "approach light credit" (lower

minimums). If the problem of cost can not be solved, many GPS approaches to non-ILS locations will not be able to take advantage of the lowest possible minimums due to the absence of appropriate lighting.

11. <u>Pavement Requirements (Exhaust Temperatures)</u>. Dr. Leverton raised this issue to see if there was any new information that could be put on the table. Mr. Todd acknowledged that the manufacturers had accepted an action item to provide information to the WG on this issue and they had not yet been able to do so. At Dr. Leverton's request, Mr. Mowbray volunteered to follow up on this matter.

12. <u>Airspace Issues</u>. Dr. Leverton raised the question, "Will anything new be available in the next 18 months?" On precision and nonprecision airspace, Mr. Smith responded that this situation has not changed since the last meeting. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. The manufacturers need to provide the WG with CTR departure profiles.

13. <u>Terminal Issues/Influences of Rotorwash: Gate Requirements</u>. The WG discussed very briefly some of the efforts underway to acquire and analyze the data needed to come to a conclusion on this matter. One WG member suggested that PANYNJ experience with turboprop operations might shed some useful light on this matter. Mr. Syms volunteered to pursue this issue with the Port Authority of New York and New Jersey (PANYNJ).

Mr. Todd commented that Bell currently expects that CTRs will park sideways at gates rather than nose-in.

14. <u>Next Meeting</u>. The WG discussed holding the next meeting in October. Dr. Leverton suggested that it would be profitable to have this meeting at Bell Helicopter in the Dallas/Fort Worth area. Mr. Heneault volunteered to host the next meeting in Ottawa. In the absence of Mr. Bonanni and concerns about FAA travel funds, a decision was not made.

(Subsequently, it was decided that the next meeting would be as follows:

Thursday Nov. 13, 1997
Boeing Helicopter Plant, Ridley Park PA (Southwest of Philadelphia)
9:00 AM to 4:00 PM)

(The location is still tentative and subject to change.)

Summary of Action Items From This WG Meeting

Vertiport Design Parameters Mr. Marinelli suggested that it would be a useful exercise to design landing facilities for the BB-609 and the CTR2000 using the guidance of AC 150/5300-13, Airport Design. Mr. Berry suggested that it would be useful to look at ICAO Annex 14 dimensions. After WG discussion on this issue, Mr. Marinelli indicated that **Mr. Bonanni** would write a white paper on this topic for consideration at the next WG meeting.

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Airspace Issues. On VFR airspace protection, Dr. Leverton commented that there is work that needs to be done. **The manufacturers need to provide** the WG with CTR departure profiles. There was not a specific volunteer for this action item.

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Safety Zones/Clearances for FATO. Mr. Marinelli volunteered that **Mr. Bonanni** would draft a white paper on this issue. **Dr. Leverton** volunteered to discuss the overrun issue with Bell and Boeing.

Taxiway Width/Parking Clearances. **Mr. Heneault** volunteered to provide Canadian criteria developed for helicopters, suggesting that they might be applicable to CTR.

Outstanding Action Items from Prior Working Group Meetings

Rejected Takeoff Performance. The manufacturers have made a commitment to provide the WG with the information on rejected takeoff requirements of the CTR2000 and the BB-609. Bell and Boeing have verbally provided initial estimates of the TLOF length required for the BB-609 and the CTR2000 under certain operational scenarios. This issue should be revisited after the FAA announces its decision on certification basis and the associated rules.

Tiltrotor Performance Model. NASA and the manufacturers have voiced different opinions on what is the best tiltrotor performance model for use in simulation testing. **Dr. Leverton** agreed to take the lead in trying to bring this issue to a consensus among the parties involved.

Vertiport IFR Approach Procedure Profile. NASA has concluded that a variable approach angle (starting at 3 degrees and transitioning rapidly to 9 degrees at 1000 feet above the landing site) is very promising and they are working to refine the details on matters such as airspeed and nacelle angle as a function of distance to touchdown. In response to a question, Mr. Decker acknowledged that the approach profiles shown on the next-to-the-last page of his briefing package were not completely consistent with what NASA is recommending. **Mr. Decker** will provide a modified version of this briefing slide.

Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will significantly shorten the life of the concrete surface. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BB-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material.

FAA/INDUSTRY VERTIPORT-HELIPORT WORKING GROUP
Working Group Minutes
April 22, 1997

Attendance

Robert Bonanni, FAA Co-chair
Tom Bosco, PANYNJ
David Cross, FAA
William Decker, NASA Ames
Scott DiBasio, HAI
George Legarreta, FAA
Dr. John Leverton, Industry Co-chair
Rick Marinelli, FAA
Norm Mowbray, Bell Textron
Deborah Peisen, SAIC
Ron Reber, Bell
Brian Sawyer, SAIC
Robert Smith, FAA
Alan Todd, Bell
Lee Zmroczek, Boeing Helicopter

Minutes

1. Introduction of New Co-Chairman and Chairman's Remarks. Mr. Bonanni introduced himself as the new working group (WG) chairman and provided some personal background. He asked that the WG members assist him in coming up to speed on full range of technical issues that face us. Mr. Legarreta bid farewell to the WG and expressed his appreciation for the support that Dr. Leverton had provided him during his term as WG Co-chairman.

2. Revision of the Heliport AC. Mr. Bonanni provided the WG with a copy of David Bennett's March 31 letter (see attached) declaring FAA's intention to revise the Heliport Design AC. He announced that the FAA plans to develop the draft AC in-house using the current AC as industry's input. He also announced that the FAA plans eventually to combine the two AC's.

3. Public Versus Private Facilities. David Bennett's March 31 letter also declares FAA's intention to delete private facilities from both the vertiport and heliport AC's. It is the FAA's position to promote safe and functional facilities without regard to their status and not to promote different levels of safety.

4. HAI/AHS Position. Dr. Leverton distributed a copy of the HAI/AHS position opposing FAA's intentions on both items 2 and 3 (see attached). Recognizing that decisions on these issues would be made outside the WG, discussion on these matters was brief.

5. NASA Tiltrotor Simulation Results. Mr. Decker briefed the WG on the results of extensive NASA tiltrotor simulation work during the 1989-1997 time period (see attached briefing package).

a. Pilot and Handling Qualities. NASA has conducted a series of tiltrotor simulations addressing approach and departure operations focused on a 40-passenger transport aircraft. Approaches between 6 and 25 degrees have been studied. Initially, very steep approaches were of interest as a way of reducing both the noise footprint and the amount of airspace required. Results indicate that 15-25 degree approaches do not appear promising. Additional avionics would be required, pilot workload would be high, and safety margin would be reduced to unacceptable levels under certain wind conditions.

Previous research on a very wide range of aircraft has led NASA to conclude that "Below 1000 feet AGL, approaches should not descend at more than 1000 feet pre minute (fpm)." Above 15 degrees, this leads to an approach speed of less than 35 knots. This slow speed presents two prominent problems. First, under certain wind conditions, the aircraft gets blown around significantly. Second, the aircraft spends an excessive amount of time at low speeds at low altitude. This is expected to result in a significant increase in the noise footprint.

NASA has concluded that 9 degrees appears to be the steepest approach angle that appears appropriate for commercial transport tiltrotor operations. Mr. Reber expressed a continued interest in approaches at angles above 9 degrees and recommended that actions not be taken that would preclude such operations. He recognized that additional research would be required before decisions could be made on the acceptability of such approaches.

NASA has also concluded that a variable approach angle (starting at 3 degrees and transitioning rapidly to 9 degrees at 1000 feet above the landing site) is promising from a noise abatement perspective and they are working to refine the details on matters such as airspeed and nacelle angle as a function of distance to touchdown. In response to a question, Mr. Decker acknowledged that the approach profiles shown on the next-to-the-last page of his briefing package were not completely consistent with what NASA is recommending. The illustrations show the test profiles, not the resulting recommended profiles.

NASA recommends a paved FATO not less than 600 feet in length. For rejected takeoff, NASA results indicate a need for a safety area between 1200 and 2000 feet long. Mr. Decker cautioned the WG, however, that this was an area where simulator limitations (issues such as visual texture) do not allow this safety area dimension to be defined precisely. Flight testing will be required.

Dr. Leverton asked the manufacturers why they have not been able to provide the WG with the information previously requested on rejected takeoff requirements of the CTR2000 and the BB-609. Mr. Reber responded that Bell and Boeing had done some work on this issue several years ago. He agreed to pursue this matter.

Mr. Decker noted that there is still research to be done on the issue of GPS sensitivity. He also called that WG's attention to certain simulator limitations and indicated that flight testing would be required on certain issues.

Mr. Reber questioned NASA's continued use of the "JVX model" of tiltrotor performance characteristics. He recommended that NASA switch to a later model developed for the V-22. Mr. Decker regarded this as a red herring and argued that NASA has an obligation to be more generic in their approach. NASA work should be applicable to a wide range of tiltrotor aircraft. Dr. Leverton suggested that the differences between the two models were probably small and that such refinement probably would not be required to address that issues that concern this WG.

Mr. Bonanni urged NASA to meet with the manufacturers and seek to reach a consensus on the issue of tiltrotor model. Then, when design data is derived from NASA's work, there will not be a dispute on it's validity on the basis of the tiltrotor model. Dr. Leverton agreed to take the lead in trying to bring this issue to a consensus among the parties involved.

The WG agreed that we will use the results of the NASA research and compare it with the results of the Civil Tiltrotor Development Advisory Committee (CTRDAC) deliberations.

b. Vertiport Marking. NASA tiltrotor simulation efforts have involved the simulation of vertiports including markings consistent with the Vertiport Design AC.

Very early NASA simulation used the "VTOL" marking symbol in the draft Vertiport Design AC (circa 1990). Simulator pilots commented that this symbol was unreadable. Based on this input and others, the original Vertiport Design WG rejected the VTOL marking symbol and adopted the "broken wheel" as the standard vertiport marking symbol. The current Vertiport Design AC recommends a minimum height of 28 feet. Simulator pilots (FAA, NASA, and industry) have found this minimum height to be inadequate. One pilot commented that the 28 foot symbol was almost invisible. Another pilot commented that it looked like an "X", the indication of a closed facility.

Subsequently, NASA became aware of the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern (see attachment showing background and results of this joint FAA/Army/industry research effort). The NASA simulation testing confirms the results of this 1967 report.

For an extended FATO, NASA recommends that the vertiport marking symbol should be placed in the middle of the FATO as an aiming point rather than putting one symbol on each end of the extended FATO as currently recommended by the Vertiport Design AC.

Simulation testing confirms that marking the FATO centerline helps to minimize cross-track dispersion during the VMC portion of vertiport approaches.

During WG discussions, Mr. Decker recalled Jim Bushee's remarks on the recommended marking of the FATO heading numbers. Currently, the height/width ratio of the FATO heading numbers are based on airport guidance developed for 3 degree runway approaches. Recognizing that vertiport approaches are expected to be significantly steeper, this is an area that should be reexamined. Mr. Decker expressed a willingness to test several candidate height/width ratios (of the FATO heading numbers) in the next tiltrotor simulation. Mr. Smith volunteered to study this issue and make recommendations.

After WG discussion, Dr. Leverton recommended the following and the WG concurred:

(1) that the "broken wheel" be retained as the standard vertiport marking symbol,
(2) that its size should be two thirds of the FATO width with a minimum dimension to be decided after further deliberations on the issue of FATO width,
(3) that the symbol should be in the middle of the FATO. (This is a change in the situation of an extended FATO since the current AC guidance recommends a marking symbol at each end of the extended FATO.

c. <u>Vertiport Lighting</u>. NASA tiltrotor simulation efforts made use of the HILS, HALS, and 1000 feet of centerline approach lights consistent with the vertiport design recommendations. Mr. Decker cautioned the WG that there are some simulator idiosyncrasies with regard to how lighting is generated and presented. Thus, this is an area where confirming flight testing is often appropriate.

With an extended FATO, Mr. Decker suggested that the approach lights should start in close proximity to the aiming point (i.e., the center of the extended FATO) rather than the edge of the FATO. He suggested that the spacing between rows of approach lights should be examined. Current recommendations are for even spacing of 100 feet. Among the other possibilities are geometrically-variable spacing and logarithmic-variable spacing. He also suggested that the minimum length of the approach light system should to be examined.

On an extended FATO, NASA testing suggests that it would be beneficial to add lighting to emphasize the aiming point (i.e., the center of the extended FATO). Mr. Decker noted that the Canadians have suggested an 8-legged lighting arrangement at the aim point. Such lighting could help provide visual emphasis that the vertiport is not an appropriate landing site for the Cessna pilot on short final during nighttime operations or marginal weather.

Regarding visual glidepath systems, simulation pilots did not use PAPI very much and VASI was useless during daytime/low-visibility situations. One WG member commented that VASI was also useless during daytime/low-visibility situations with fixed-wing aircraft. NASA has concluded that the visual glidepath system should be located in close proximity to the FATO centerline rather than off to one side. Mr. Decker spoke briefly about the flush installation of such a system.

NASA has concluded that additional research is required on vertiport lighting. Mr. Decker recommended that such research should include cold-cathode lighting, light-pipe lighting, and the Navy shipboard heliport lighting.

Mr. Zmroczek commented that the recent FAA-sponsored obstacle-rich-environment (ORE) research has demonstrated that enhanced lighting results in more consistent approaches. He asked when this document would be published.

d. Noise. Just prior to this portion of the NASA briefing, Mr. Bonanni provided copies of recommendation from Charles Cox, Bell Helicopter. Mr. Decker commented that Mr. Cox's paper contained excerpts from a NASA/Bell paper to be presented at the AHS forum in Virginia Beach, April 29 - May 1 (see attached paper). Mr. Decker's briefing contained excerpts from the same paper. Mr. Decker cautioned the WG that, due to the way that the noise data was collected, these data are not directly comparable with the CTRDAC noise data.

NASA has concluded that blade-vortex interaction (BVI) is the dominant noise source for CTR. Since BVI is more prominent during descent and deceleration, rather that ascent, this helps to explain why the tiltrotor is noisier during approaches than departures. Rapid ascent during departure results in a limited exposure time in comparison with the long time on approach. Mr. Decker discussed excerpts for the "Fly Neighborly Guide" addressing "fried egg" helicopter noise plots as a function of airspeed and rate of climb/descent. Helicopter noise footprints can be reduced by avoiding the "fried egg', particularly its center. Recent noise data collection has started to define the tiltrotor "fried egg". Preliminary results indicate that a 6 degree approach would take the tiltrotor through the part of the flight envelope where the highest noise generation takes place.

Noise considerations have significantly influenced the NASA conclusion that a variable approach angle (starting at 3 degrees and transitioning rapidly to 9 degrees at 1000 feet above the landing site) is very promising and they are working to refine the details on matters such as airspeed and nacelle angle as a function of distance to touchdown.

Thus, it appears that IFR CTR vertiport approaches are likely to be significantly different than IFR helicopter vertiport approaches. One WG member questioned whether the FAA would develop separate TERPS for vertiport approaches or whether they would only develop the more restrictive of the two. Mr. Smith voiced his opinion that the FAA would develop two different procedures for approaches to the same vertiport. However, there was not a FAA Flight Standards representative in attendance to provide an authoritative answer to this question.

Mr. Decker mentioned that tiltrotor noise has a lower frequency than helicopter noise. As a result, people can be expected to find it less annoying. However, the lower frequency noise travels further (i.e., it attenuates less as a function of distance) than the higher frequency helicopter noise. One WG member suggested that consideration of the ramifications of this issue is outside our charter. No one objected to this statement.

6. Certification Standards for the BB-609. Concerning Category A and B operations, Mr. Smith provided a status report on his discussions with the FAA Rotorcraft Directorate in Fort Worth TX. The FAA has not yet made a decision on this issue and does not expect to make such a decision until after Bell/Boeing has developed a BB-609 simulation capability. Mr. Reber stated that the manufacturers are still working on details of BB-609 design. Thus, a BB-609 simulation capability is at least six months away. Several WG members questioned why the FAA's decision would be dependent on a simulation capability. The simulator may be very useful in providing a refined answer on certain aspects of aircraft performance. However, it is not clear why a simulator would be required before the FAA could make a decision on this aspect of the certification basis. Mr. Smith volunteered to pursue this matter further.

7. STOL/VTOL Operation Based on CTR Performance Characteristics. Mr. Reber stated that Bell is not yet comfortable with releasing BB-609 performance characteristics. What they know about BB-609 performance is heavily based on the use of the XV-15 simulator and the XV-15 is an under-powered aircraft. Dr. Leverton suggested that the information needed by the WG does not require a high degree of refinement. We can work with preliminary data now and refine our design recommendations as better information becomes available. Dr. Leverton volunteered to work with Bell and Boeing to see if preliminary performance characteristics could be provided. (Bell has the lead on aircraft performance data for the BB-609. Boeing Helicopter has the lead on aircraft performance data for both the V-22 and the CTR2000.)

8. IFR Airspace - Precision and Nonprecision Approaches. Mr. Smith stated that guidance on vertiport nonprecision approach airspace can be developed now based on FAA Order 8260.42, Helicopter Nonprecision Approach Criteria Utilizing the GPS. However, developing guidance on vertiport precision approach airspace requires a decision. We could start now to develop guidance based on helicopter MLS TERPS. A second possibility would be to develop guidance based on helicopter CAT 1 GPS TERPS. The second choice will probably result in smaller airspace, however, these TERPS may not be available for many months. With our July 1998 AC publication date in mind, the WG decided to do the following:

(a) Develop guidance on vertiport nonprecision approach airspace based on FAA Order 8260.42, Helicopter Nonprecision Approach Criteria Utilizing the GPS.

(b) Develop guidance on vertiport precision approach airspace based on heliport MLS TERPS.

(c) Make use of CAT 1 GPS TERPS if they become available prior to the finalization of the revised Vertiport Design AC.

9. Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. Mr. Bonanni stated FAA's desire to address vertiport pavement issues in FAA AC150/5320-6, Airport Pavement Design and Evaluation, and to reference this pavement AC in the revised Vertiport Design AC. The WG concurred with this approach. Mr. Bonanni introduced David Cross, an FAA employee with expertise on pavement. He will be the FAA contact on test issues. (Mr. Cross can be reached at 202-267-8744.)

Mr. Smith expressed his concern about the long-term effects of tiltrotor engine exhausts on the life of concrete and pavement joint material. Anecdotal information appears to indicate that concrete is not adversely affected by tiltrotor engine exhausts. However, anecdotal information can not answer our questions about long-term effects. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will shorten the life of the concrete surface from 20 years to 5 years. Hopefully, by providing our pavement specialists with the tiltrotor engine exhaust temperatures, we can avoid such an expensive surprise.

Mr. Reber and Mr. Zmroczek volunteered to provide Mr. Cross with the engine exhaust temperature data required on the BB-609, the V-22, and the CTR2000.

10. Land-use Planning. Mr. Bonanni briefed the WG on NEPA requirements and on FAA Order 5050.4A, Airport Environmental Handbook. Both documents apply to all public airports including public heliports and vertiports. He noted that Order 5050.4A is currently being revised and the next version is expected to be considerably larger than the current 120 page document. In view of the size of this order, Mr. Bonanni proposed to reference this document in the Vertiport Design AC rather than attempting to address the many issues it covers. The WG concurred with this approach.

Dr. Leverton raised the question of whether this decision negated the need for the approach discussed at the last WG meeting. At that time, the WG appeared to favor addressing the following topics:

(a) The need to integrate vertiports (and heliports) into metropolitan transportation planning per the Interstate Surface Transportation Efficiency Act (ISTEA).

(b) Land Use Planning: as a minimum, this section should mention route definition over areas of high ambient noise such as major highways.

(c) Noise contours and noise abatement.

(d) Citizen involvement in the planning process.

After discussion, the WG concluded that referencing Order 5050.4A would adequately address items (b) and (d). However, items (a) and (c) still need to be address in the Vertiport Design AC. On item (a), the WG recognized that the pending Congressional reauthorization of ISTEA may be called NEXTEA.

11. <u>Land-use Planning - Noise Contours</u>. Dr. Leverton informed the WG of his discussions with Mr. Cox (Bell) concerning an approach to addressing CTR noise footprints. With the 40-passenger CTR, Mr. Cox recommended that the WG follow the lead of the CTRDAC and use the material that they have published. With the 9-passenger CTR, Mr. Cox recommended that the WG should develop a noise footprint for two operations per day and a table showing how the size of this footprint increases as the average daily number of flight operations increases. The WG concurred with this approach. Dr. Leverton cautioned the WG that the LDN metric does not work well at less than twelve operations per day. The WG did not discuss potential changes in approach should this prove to be a problem.

12. <u>Rotorwash</u>. Mr. Smith touched briefly on prior FAA rotorwash research. On the basis of this work, he noted that the WG had concluded, at the last meeting, that the 40-passenger CTR would not air-taxi or hover-taxi at a vertiport. Regarding the 9-passenger CTR, however, there was some uncertainty as to whether this conclusion also applied. The WG confirmed that their conclusion also applies to the 9-passenger CTR. The WG agreed that vertiport design guidance should be developed on the assumption that no tiltrotor will air-taxi or hover-taxi at a vertiport and that this assumption should be stated in the AC.

Mr. Smith expressed his opinion that this appears to be a prudent choice since it significantly reduces both the risk of rotorwash-induced accidents and vertiport land requirements. He noted, however, that at the time of the last WG meeting, no ground-hover CTR rotorwash data had ever been collected. With this in mind, the FAA has previously requested that certain ground-hover XV-15 rotorwash data be collected by Bell Helicopter and that similar data be collected by Patuxent River on the V-22. Bell has completed their testing. Patuxent River testing is scheduled for sometime this summer.

The FAA plans to use the XV-15 data to estimate the magnitude of BB-609 rotorwash. Similarly, the FAA plans to use the V-22 data to estimate the magnitude of CTR2000 rotorwash. Both efforts will involve the use of the previously developed rotorwash model entitled ROTWASH. Coupled with a civilian rotorwash threshold, these data will allow us to define separation criteria for the protection of passengers exposed to rotorwash at vertiports.

Mr. Smith suggested that vertiport gate separation requirements should be developed for each of the following scenarios:

a. Gate separation requirements when operations at adjacent gates are unconstrained and enclosed jetways/loading bridges are not used. Large separations between gates may be required in order to protect passengers from rotorwash during loading and unloading at one gate while a second CTR is entering or departing an adjacent gate.

b. Gate separation requirements when operations are somewhat constrained and enclosed jetways/loading bridges are not used. "Operations are somewhat constrained" means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. However, the CTR at the adjacent gate may have rotor's turning. This application would be appropriate when vertiport capacity is not a critical issue. (This case could be ignored if we are certain that rotors will NOT continue turning while at the gate.)

c. Gate separation requirements when operations are constrained and enclosed jetways/loading bridges are not used. ("Operations are constrained" means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. In addition, the CTR at the adjacent gate will NOT have rotor's turning.)

d. Gate separation when enclosed jetways/loading bridges are used.

By developing separation requirements for each of these scenarios, it would provide industry with the flexibility to choose from among these scenarios on a case-by-case basis. The WG agreed with this approach.

Looking at the 2010 time period for the introduction of the 40-passenger CTR, Mr. Smith speculated that passenger loading bridges may be a minimum requirement. The factors driving this requirement are legal requirements for loading and unloading of disabled passengers and competitive marketing pressures on the issue of passenger comfort during loading and unloading. With this revision, however, it is premature to adopt loading bridges as a minimum requirement.

13. Terminal Capacity. Mr. Bonanni stated the FAA's intentions to combine AC150/5360-9, Planning and Design of Airport Terminal Building Facilities at Nonhub Locations, and AC150/5360-13, Planning and Design Guidelines for Airport Terminal Facilities. He noted that the responsibility for this effort was his. Mr. Smith expressed his opinion that the recommendations of these advisory circulars would be adequate on a number of issues. But on other issues, such as number of gates required and how to optimize vertiport capacity, these documents were clearly inadequate. Mr. Bonanni suggested that, on such issues, the Vertiport Design AC should state requirements in broad terms since the subject matter will not have reached a maturity that would justify very specific guidance. The WG concurred with this approach.

14. Clearances. Due to time constraints, this issue was not addressed.

15. Other Issues. Mr. Smith provided the WG with several white papers for discussion at future WG meetings. These are attached to these minutes.

16. Next Meeting. The next meeting is scheduled for Tuesday July 22 at a Washington-area location TBD. (Subsequently, it was decided that the next meeting would be as follows:

Tuesday July 22, 1997, 9:00 AM to 4:00 PM
Textron Inc. 1101 Pennsylvania Ave. NW, Suite 400
Washington DC 20004

Summary of Action Items

Certification Standards for the BB-609. Concerning Category A and B operations, the FAA has not yet made a decision on this issue and does not expect to make such a decision until after Bell/Boeing has developed a BB-609 simulator capability (at least six months downstream). Several WG members questioned why the FAA's decision would be dependent on a simulation capability. **Mr. Smith** volunteered to pursue this matter further.

FATO Heading Markings. Currently, the height/width ratio of the FATO heading markings are based on airport guidance developed for 3 degree runway approaches. Recognizing that vertiport approaches are expected to be significantly steeper, **Mr. Smith** volunteered to study this issue and make recommendations. **Mr. Decker** expressed a willingness to test several candidate height/width ratios (of the FATO heading markings) in the next NASA tiltrotor simulation.

Rejected Takeoff Performance. The manufacturers were asked on why they have not provided the WG with the information previously requested on rejected takeoff requirements of the CTR2000 and the BB-609. Bell and Boeing had done some work on this issue several years ago. **Mr. Reber** agreed to pursue this matter.

STOL/VTOL Operation Based on CTR Performance Characteristics. Mr. Reber stated that Bell is not yet comfortable with releasing BB-609 performance characteristics. **Dr. Leverton** volunteered to work with Bell and Boeing to determine if preliminary performance characteristics can be provided.

Tiltrotor Performance Model. NASA and the manufacturers have voiced different opinions on what is the best tiltrotor performance model for use in simulation testing. **Dr. Leverton** agreed to take the lead in trying to bring this issue to a consensus among the parties involved.

Vertiport IFR Approach Procedure Profile. NASA has concluded that a variable approach angle (starting at 3 degrees and transitioning rapidly to 9 degrees at 1000 feet above the landing site) is very promising and they are working to refine the details on matters such as airspeed and nacelle angle as a function of distance to touchdown. In response to a question, Mr. Decker acknowledged that the approach profiles shown on the next-to-the-last page of his briefing package were not completely consistent with what NASA is recommending. **Mr. Decker** will provide a modified version of this briefing slide.

Vertiport Pavement (and Pavement Joint) Material - Tolerance to Engine Exhausts. After we have constructed a number of vertiports, we don't want to learn that tiltrotor engine exhaust will shorten the life of the concrete surface from 20 years to 5 years. **Mr. Reber** and **Mr. Zmroczek** volunteered to provide Mr. Cross (FAA) with the required engine exhaust temperature data for the BB-609, the V-22, and the CTR2000. Mr. Cross will use these data to develop guidance on the appropriate vertiport pavement material.

HELIPORT/VERTIPORT MARKING SYMBOLS

Excerpt from FAA/RD-93/17 Summarizing the 1967 Report TR 4-67,
Development Study for a Helipad Standard Marking Pattern

2.5.1 Heliport TLOF Marking Symbols - Requirements. In the mid-1960's, the FAA and the U.S. Army developed a standard heliport marking symbol. This effort started with an examination of current practices, discussions with helicopter pilots, and the development of a list of fundamental requirements for a marking symbol. On a consensus basis, the FAA and industry concluded that the heliport marking symbol should provide the following guidance to the pilot during an approach:

a. identification of a heliport site from a minimum distance of one mile (1.6 km), measured on the ground, at viewing angles from 5 to 20 degrees inclusive under VFR conditions.

b. a means of directional control to the pilot during the approach to the helipad.

c. a field of reference to assist the pilot in maintaining the correct attitude of the helicopter during the approach to the helipad.

d. assistance to the pilot in controlling the rate of closure to the helipad.

e. a point of convergence to the desired touchdown or hover area.

f. assistance to the pilot in determining the location of the helicopter with respect to the touchdown or hover point when the helicopter is directly over the helipad.

2.5.2 Heliport TLOF Marking Symbols - Testing and Results. Once the list of section 2.5.1 was accepted as a desirable list of characteristics, various marking patterns were tested to determine how well they could meet these requirements. Following laboratory testing and scale-model studies, flight test evaluation was conducted....

Among the conclusions are the following:

a. A minimum pattern size of 75 feet is needed to be identifiable from a distance of one mile at a viewing angle of 5 degrees.

b. Pattern identification works best when the pattern is between 50 and 83 percent of the size of the helipad. (Smaller patterns tend to disappear. Larger patterns tend to blend with the edge markings.)

c. A ratio of line width to pattern size of 0.07 provides the best pattern definition. (Narrower lines tend to disappear. Wider lines tend to give the impression that the entire pad is painted

APPENDIX B.
FAA/INDUSTRY VERTIPORT DESIGN WORKING GROUP WHITE PAPERS

This appendix contains these white papers arranged in the following order:

August 24, 1999	**The Need for Conservative Vertiport Design Recommendations** Robert D. Smith
September 16, 1999	**NASA Comments and Responses to Dr. John Leverton's "Vertiport Design – Industry Position"**, William A. Decker
August 27, 1999	**Vertiport Design – Industry Position,** Dr. John Leverton
September 1998	**Civil Tiltrotor - Maneuvering and Ground Taxi Rotorwash Characteristics,** Samuel W. Ferguson
August 24, 1998	**CTR Rotorwash – Hazard Threshold for Civilian Passengers,** Robert D. Smith
May 27, 1998	**Commuter Aircraft Ramp and Passenger Safety Practices - Possible Application to Tiltrotor Aircraft**, Raymond A. Syms
Nov. 17, 1997	**CTR Steep Approach Profile for Noise Abatement,** William A. Decker
July 22, 1997	**Vertiport Standard Marking Symbol**, Robert D. Smith
July 22, 1997	**Vertiport TLOF Azimuth Designations**, Robert D. Smith
April 22, 1997	**Safety**, Robert D. Smith
April 22, 1997	**Vertiport Capacity**, Robert D. Smith
April 22, 1997	**Vertiport Terminal Gate Separations**, Robert D. Smith
April 22, 1997	**Passenger Loading Bridges and Passenger Comfort,** Robert D. Smith
April 22, 1997	**CTR Rotorwash Effect on Civilian Passengers,** Robert D. Smith
April 22, 1997	**Accessibility to Individuals with Disabilities or Special Needs,** Robert D. Smith

VERTIPORT DESIGN AC REVISION - WHITE PAPER
THE NEED FOR CONSERVATIVE VERTIPORT DESIGN RECOMMENDATIONS

Robert D. Smith, AND-520

September 30, 1999

Background – Difficulties in Modifying the FAA Heliport Design AC

In the last twenty years, the FAA has revised the Heliport Design advisory circular (AC) several times. The first of these revisions took place in 1984-1988. The second revision took place in 1992-1994. The third revision is still underway, 1997-1999. Each of these revisions was accomplished in concert with significant Industry participation via an FAA/Industry Heliport Design Working Group (WG). Typically, when a revision was underway, the WG met either quarterly or monthly as dictated by need and availability of FAA and Industry personnel. The FAA originally anticipated that each of these revisions would be accomplished in 12 months or less. However, the FAA was not able to meet their original approval and publication milestones on any of these AC modifications. Revision of the AC has generally taken two to four times longer than originally scheduled.

These revisions have also demonstrated the level of difficulty involved in making changes to FAA heliport design recommendations. Looking back at changes that reduced the recommended size of a particular heliport parameter, such changes were generally been relatively easy to make. Looking back at proposed changes that would have increased the recommended size of a particular heliport parameter, such changes were exceedingly difficult to make. Industry has invariably insisted upon voluminous written justification for any such changes. Even with such justification, Industry has almost invariably opposed any changes that would have increased the recommended dimensions of a heliport parameter. Reaching a consensus on a proposed decrease in the recommended size of a heliport parameter has generally been relatively easy. Reaching a consensus on a proposed increase in the recommended size of a heliport parameter has generally been difficult or impossible.

Background – The Vertiport Design AC

An FAA/Industry Vertiport Design Working Group (WG) developed the first version of the Vertiport Design AC during 1989-1991. At the time, the aviation community had very little operational experience with tiltrotor aircraft and all of that experience was with experimental or developmental aircraft. Still, considering the limited knowledge available, this WG developed a credible set of design recommendations. Over the last eight years, however, the aviation community has learned a great deal about tiltrotor aircraft. This has been accomplished through design studies, marketing studies, the efforts of the Civil Tiltrotor Development Advisory Committee (CTRDAC), and through additional tiltrotor flight testing of experimental and military aircraft. Clearly, there is a need to revise the Vertiport Design AC and a revision is underway.

In various recent conversations, spokesmen for the principal tiltrotor manufacturer have made it clear that they are interested in a Vertiport Design AC that recommends the ABSOLUTE minimum design requirements. Certainly, minimum design requirements are what an AC is supposed to contain. But developing ABSOLUTE minimum design requirements presupposes that sufficient knowledge is available to develop such guidance. While the state of tiltrotor knowledge has been significantly advanced since 1991, there are still many areas where this knowledge is incomplete. Developing ABSOLUTE minimum design requirements also presupposes either that the risk that these recommendations will later be found inadequate is very small or that it will be possible to modify such guidance material in a timely manner if they prove to be inadequate. In view of the limited operational experience with the tiltrotor, the risk that these recommendations will later be found inadequate is far from small. In addition, experience with the Heliport Design AC raises serious questions about the FAA's ability to modify inadequate heliport or vertiport design guidance in a timely manner.

Discussion – Difficulties in Affecting Changes in the Design of Existing Heliports

Contrary to popular belief, the FAA does NOT regulate private heliports (or private airports either, although that topic is outside the scope of this paper). The statutory authority for such regulation belongs to the States. Some States have exercised this authority by developing extensive heliport regulations. Some have developed limited heliport regulations. Some States have no heliport regulations at all. Even large States will sometimes admit that they do not have the expertise or the resources to develop extensive heliport design regulations on their own. Consequently, State heliport regulations are generally based on selected parts of the FAA Heliport Design AC. When the FAA Heliport Design AC is modified, heliport owners are under no obligation to modify their existing heliports in response unless this is dictated by the regulations of the State in which the heliport is located. In a very few States, revisions of the Heliport Design AC are adopted automatically by State law. Generally, however, it takes a State a year or more to modify their State heliport regulations to adopt a revision of the FAA Heliport Design AC.

In the last twenty years, each time the Heliport Design AC has been changed, Industry has insisted that the modified document contain wording stating specifically that no changes need to be made to existing heliports. A limited number of State aviation authorities may choose to modify their State heliport regulations consistent with the latest Heliport Design AC. However, a recent National Association of State Aviation Officials (NASAO) survey has shown that the number of States who make this change retroactive is very small (perhaps only 1 or 2). By and large, any changes made to existing facilities are likely to be at the sole discretion of the heliport owner. Thus, design changes to existing heliports occur very slowly if at all.

With vertiports, the author is not aware that even one of the 50 States has developed or is developing design regulations. In the long term, one can expect that, like heliports, design changes to existing vertiports will be slow to occur. Over the next several years, no State regulations on vertiports are likely to be enacted. Thus, private vertiports could be largely unregulated by anyone for the foreseeable future. In revising the current Vertiport Design AC, the FAA has announced their intention to combine the Heliport and Vertiport Design AC's. While this may encourage some of the States to address vertiports in their regulations, it is likely to be several years before this occurs.

Conclusions

Reaching a consensus on a proposed decrease in the recommended size of a heliport parameter has generally been relatively easy. Reaching a consensus on a proposed increase in the recommended size of a heliport parameter has generally been difficult or impossible. There is every reason to expect that, with vertiports, the situation will be very similar.

There are many in the rotorcraft industry who talk about why FAA heliport design criteria ought to remain as it was in the 1970's. There are others who even look back nostalgically to the FAA heliport design criteria of the 1950's. When revisions to the FAA's heliport design recommendations are proposed, many in Industry talk about why it would be a great hardship if the FAA adopts these changes. But very few people talk about how one should scientifically determine what heliport design criteria requirements ought to be. Even fewer have focused on the published reports that document what the FAA has done in this regard.

FAA heliport design recommendations have for years been largely based on the subjective opinions of industry helicopter pilots. Generally, such thinking represents about a two-sigma dispersion in pilot performance. As a consequence, the safety margin provided by FAA heliport design recommendations is not very large. (Consider, by comparison, a precision approach where clear airspace is provided for a six-sigma variability in pilot performance.) Intense pressure from the helicopter industry has maintained this situation over a period of four decades. By contrast, FAA airport design recommendations have gradually increased as a result of operational experience, research, and testing.

Recommendations

The tiltrotor is a new **type** of aircraft and operational experience is very limited. With the initial delivery of the BA609 expected in 2002, the Industry can not expect to have significant operational experience before about 2005. Until we have significant operational experience with a civil tiltrotor, the FAA should take a conservative approach with vertiport design recommendations. It will be possible to reduce vertiport design recommendations if there is technical justification to do so. Based on experience with the Heliport Design AC, however, it will be difficult or impossible to increase vertiport design recommendations in a timely manner once vertiports have been built.

NASA COMMENTS AND RESPONSES TO
DR. JOHN W. LEVERTON's "VERTIPORT DESIGN – INDUSTRY POSITION" PAPER
Ref. Fjwl067.99
William A. Decker
September 16, 1999

Dr. Leverton posed several design and operations issues for both large and small tiltrotors in a message finally received at the Vertiport Design Guide review meeting, September 1, 1999. The following comments represent amplification of the NASA presentation at the June '98 working group meeting.

1. Small pad VTOL Operations

The NASA CTR-5 experiment included Helicopter "Category A"-type VTOL operations for the higher single engine contingency power studied. This short time rating provided sufficient power to hover in ground effect up to a ten-foot wheel height. With this power available, a viable back-up departure technique could be employed. Pilots backed up to a height of around forty feet while keeping the pad in view. Until the take off decision point was reached, an engine failure necessitated a land-back. Figure 1, below, was presented at the June '98 meeting. It documents the land-back performance achieved.

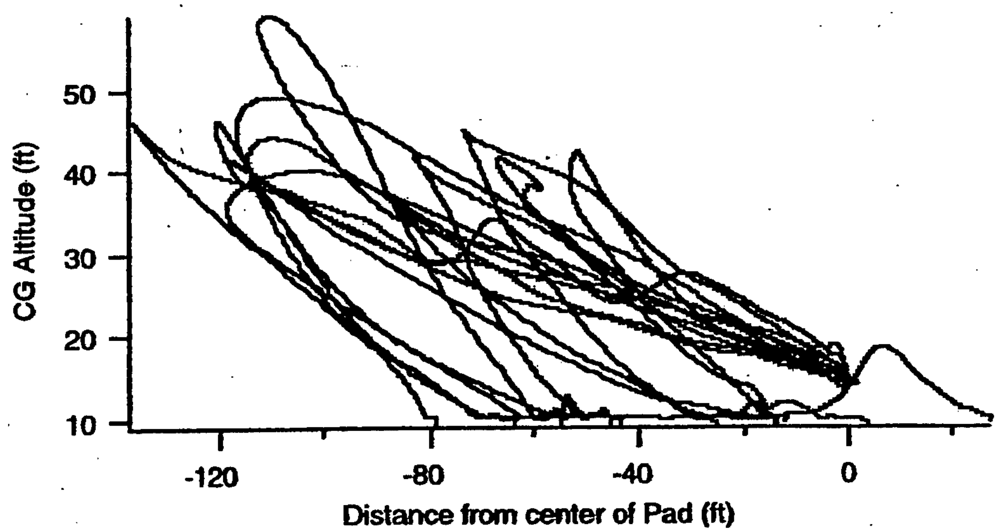


Figure 1. Hover back-up take-off OEI land-backs (rejected take-offs). Engine failures 35<height<45 feet.

The table lists the land-back touchdown and stop position statistics. For engine failures introduced at several heights during the back-up maneuver.

Height	Avg TD	Min TD	Max stop
All	-53	-87.2	26.9
25 - 35	-43	-79.7	13.2
35 - 45	-46.7	-80.9	26.9

Table 1. Rejected VTOL Take-off land-back statistics.

Several caveats bear repeating for this data:

- OEI short-time power was assumed sufficient for hover in ground effect to 10 feet. For the aircraft model used, this represented 87% of the hover out of ground effect value. Do note that ground effect is a key element in providing performance. Operation over water or off raised decks would not achieve this performance boost.
- The data was collected in the NASA Vertical Motion Simulator. This facility has excellent motion cues. Visual cues provided only modest ground texture and a somewhat limited field of view. The FOV was probably similar to a real aircraft--we seem to keep adding to the cockpit panel size. The reduced ground texture affects height rate and absolute height above ground perception. That achieved in the simulator might be similar to a poor weather and night lighting situation. That said, this is still likely to be the best data available. This is inherently very dangerous testing--H-V testing.
- Only a limited number of evaluation runs were performed for this operation. This leads to conservatism on recommending facility size.
- The lower contingency power rating (77% of HOGE power) was not tested for this operation. It simply did not have sufficient power on one engine to keep from hitting the earth mightily for failures close to the take-off decision point. Only the two contingency power ratings were investigated.

It would be useful to compare notes with Tom Wood's data and methodology. Many factors lead to conservatism, including issues of pilot training, experience, currency and awareness. A more thorough study with appropriate pilot-"subjects" might provide higher confidence in the achieved performance. The NASA CTR-5 experiment sought to provide at least a preliminary envelope. I believe the 250 ft long pad was selected as a compromise "SWAG", with some input from Boeing. Note that the landings tend to be short of the center point (zero reference in figure 1), but the stopping point was often beyond the center point. It's unclear whether a bit of an offset (taking off from the "forward" part of the pad--or at least guiding on that point) would help the overall size. Recall also, that the touchdown point recorded concerns the aircraft center of gravity. The main gear would be a bit aft of this point and the entire aircraft tail would be well aft.

2. Vertiport TLOF Size

Generally speaking, aircraft size affects lateral size of the facility. Aircraft performance dominates the longitudinal distances. Only when the facility size is reduced to a small pad, such as discussed in item 1, does the aircraft longitudinal size begin entering the problem. Even then, the size differences between a V-22 and a BA-609 represent only a small fractional difference--on the order of five or ten feet. That's well inside the statistical significance band for the current data.

3. Instrument Meteorological Conditions

The NASA CTR-series of experiments have concentrated on transport tiltrotor approach operations. Limited visibility and winds have always been a major part of the test matrices. Over the course of several experiments, we settled on four primary evaluation conditions for approaches:

a) Clear, Calm
b) Clear with 10 knot cross-wind and "moderate" turbulence (4.5 fps rms)
c) Limited visibility (almost all cases were 200 ft ceiling and 2000 ft RVR)
d) Limited visibility (200ft ceiling/2000ft RVR) with 10 knot crosswind and moderate turbulence

The 200 ft ceiling was selected to match up with a similar Landing Decision Point (LDP) for use with a nine degree approach. The problem faced is the deceleration longitudinal distance (about a quarter mile needed) needed to decelerate from an LDP flight condition of 50 knots. A shallower approach angle, e.g. 'standard' three degree, might lower the ceiling, but not the horizontal (RVR) visibility requirement. All of this has been aimed at limited OEI performance.

Better OEI performance provides for lower visibilities--it all revolves around the landing or take-off decision points. During the CTR-5 experiment, operations with the higher contingency power (87% HOGE--HIGE to 10 ft) were successfully conducted with a 100 ft ceiling. If you have the power to hover OEI, many of the operational problems--including visibility--go away. Indeed, with the 87% contingency rating, we successfully conducted 15 degree approach operations. Without such hover performance, however, one must operate with higher airspeeds at the decision point. This results in higher visibility requirements.

4. STOL Operations

As we investigated various take-off operations, ESTOL (Extremely Short Take-Off and Landing) emerged as a response to limited OEI performance. Traditional rolling take-offs derive from fixed wing practice. Brakes are released, the aircraft accelerates beyond the OEI flight speed, and then rotates for take-off and climb out. An engine failure prior to rotation is supposed to result in an aborted take-off. Braking distance must be provided to stop on the runway from a failure occurring at the rotation point and speed.

In contrast to the conventional rolling take-off model, we found that it was very hard to keep a tiltrotor on the ground or to land-back--even from failures introduced at quite modest speeds. The distances consumed in any land-back and braking were large--in spite of a tiltrotor's large "air-brakes"--rotors at the aft position. In concert with several certification authority pilots (US-FAA and UK-CAA), we eventually settled on a brake release commit to departure. This was far simpler to perform with minimal pilot training or concern. Proof was found by taking off with just the single engine operating at its short-time rating. For our transport aircraft, we could clear 35 feet by the end of a 600 feet long TLOF. The conventional aborted take-off alternative was much longer, as the reference inquiry notes. Of course, this was all done in a simulator, but this brake release commit to take-of technique is based on more reliable cueing (almost none needed!) than plague some of the landing results. Anecdotal evidence supporting the simulator findings is in the form of observations of routine operations with the XV-15 when operated at Ames and in runway operations with a V-22. Tiltrotors with modest forward nacelle position (70-75 degrees) simply want to lift off. Further precedence for a brake-release take-off decision may be found in operations of the Breguet 941 during the US STOL demonstration program. That cross-shafted STOL airplane also had a brake-release commitment.

Points favoring the brake-release take-off STOL technique:

- Better Handling Qualities
    - Rejected Take-Off not a factor
    - Sets pilot's mind--no decision required
    - Less critical cockpit procedure
        - speed not a critical issue
        - copilot will still monitor engine condition display, but no critical decision hangs on prompt call-out of critical speeds
- Eliminates hover-in-ground-effect handling problem of "lateral darting"
- Easily repeatable procedure
- Aircraft wants to "leap" into the air prior to V1 (OEI minimum airspeed--out of ground effect)
- Could not cause a problem for pilots during simulation experiments. ESTOL was a "no-brainer."
- Engines brought up smoothly--turbines like this treatment.
- At aircraft unstick (lift-off), aircraft rotates below the rotors, but sufficient acceleration still achieved with 75 degree nacelle setting.

Removing the rejected take-off area and requirement with brake-release take-off commitment looks very promising.

5. Rejected Take-Off Considerations

NASA simulation experience with rejected take-offs is very much "preliminary." In spite of a lot of time spent by several pilots in both fixed-base development and motion platform evaluation, we still see a lot of technique variation. The principal offender is the reduced visual cueing needed for height rate and absolute height judgement. Figure 2 shows rejected take-off trajectories for a VTOL operation for failures introduced between 15 and 20 knots.

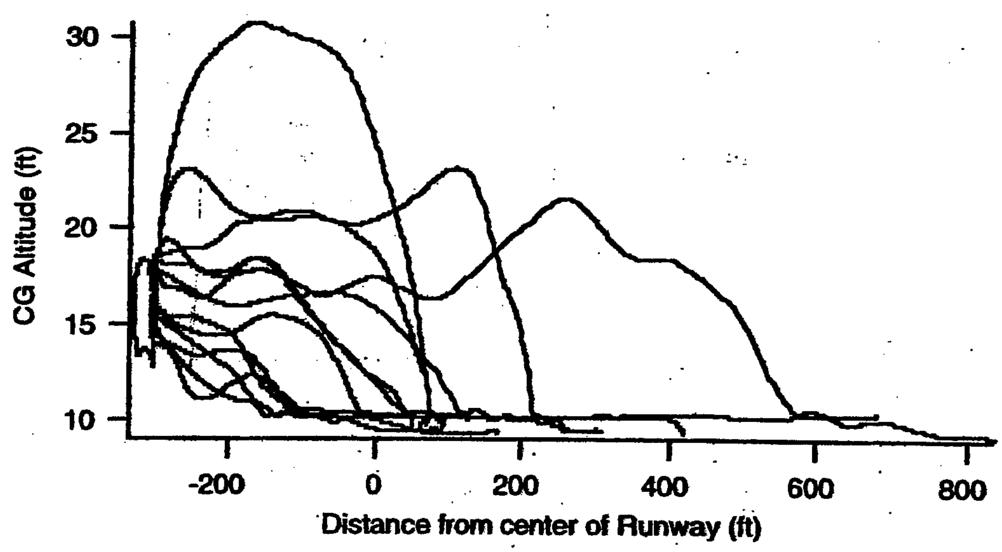


Figure 2. Rejected VTOL take-offs, Engine failures: 15<velocity<20 knots.

The extreme variation in touchdown points illustrated in this figure points to the difficulty faced. These were experienced rotorcraft pilots with many thousands of hours in rotorcraft. "Finding the ground" was the issue. Conservatism in data interpretation AND in facility planning for such an operation is advised.

VERTIPORT DESIGN -INDUSTRY POSITION
[Discussion Note]

Dr. John Leverton, AHS International
Issue 5 (27 August '99)

[Note: (i) This document is based on recent discussions with Bell Helicopter Textron and previous discussions with Boeing.
(ii) All dimensions quoted refer to *minimum* recommended values.]

1. DESIGN CATEGORIES TO BE CONSIDERED

1. VTOL PRIVATE (PPR)
2. VTOL GENERAL AVIATION
3. VTOL TRANSPORT - Minimum: 'Zero Field' Length
   - 'Free Field' Length
4. STOL PRIVATE (PPR)
5. STOL GENERAL AVIATION
6. STOL TRANSPORT

For each (a) VFR, (b) non-precision IFR and (c) Precision IFR should be considered.

2. DEFINITIONS

(a) GENERAL AVIATION:

GENERAL AVIATION VERTIPORT: Vertiport compatible with *normal CTR operations,* where CTR is only required to meet Part 135 standards and hence are NOT required to meet Transport Category CAT A/Class 1 performance standards i.e. vertiport designed for CAT B/Class 2 operations. Ground space and airspace based on consideration of all engines operating (AEO) performance.

(b) TRANSPORT:

TRANSPORT VERTIPORT: Vertiport compatible with CTR CAT A/Class 1 *transport* operational requirements. These should cover minimum size facilities where 'zero or short field length' using, say, rearward takeoffs are employed to large facilities which encompass 'free field RTOA'.

PRIVATE (PPR):

Vertiports to be used by private operators (Part 91 operators) where *prior permission* is required to land. PPR should have the same basic characteristics as a General Aviation facility with exception that the 'safety zones' can be less and 'protection zones' are NOT required. [Same concept is applied for heliports.]

(d) FATO/TLOF:

(i) VTOL – For VTOL operations the TLOF, FATO and RTOA are treated as separate entities and separate dimensions are quoted. This is different from the current AC format and has been adopted to aid clarity of understanding. [The current FAA and ICAO formats consider 'elongated FATOs', which encompass the basic FATO and RTOA, while Transport Canada use separate FATO and RTOA areas as used in this note.]

(ii) STOL – For STOL there does not appear to be any format directly applicable to CTR operations. For this evaluation it has been assumed that the TLOF includes the '*rollway*' and the FATO includes the *rollway* plus where applicable the '*stopping distance*'.

3. DESIGN CONSIDERATION:

(a) VTOL – this should be based on 'helicopter type considerations,' since the CTR will takeoff and land like a helicopter.

(b) STOL – these should be based on the unique STOL characteristics of the CTR, which are somewhat similar to those associated with a STOL aircraft. The CTR will normally not need to land as a true STOL vehicle because of the 'lower landing weight' at the end of the journey, but run-on landings will most likely be used.

4. VERTIPORT DESIGN (DIMENSIONS) CONCEPT:

(a) VTOL Private (PPR) / General Aviation:

This is based on the assumption that the CTR will takeoff and land like a helicopter – thus 'heliport/helicopter' requirements are considered applicable.

(b) VTOL Transport:

The minimum dimensions are based on the use of estimates applicable to a 'rearward takeoff' technique, similar to that used on helicopters to obtain the minimum/zero field length for 'CAT A operations' at confined heliports and elevated helipads/heliports. This will be associated with weight/payload' limitations. A FATO of 1.5T

is recommended. [Note: Based on current helicopter experience this may, however, require the TLOF length to be increased to 1.5T and the FATO length to 2T: **this requires further study**.]

To enable the weight/payload to be maximized, a takeoff profile akin to the 'free field profile' associated with current helicopters is likely to be used. Assuming a realistic temperature/pressure density, this would require an extended length (RTOA) in the order of between 1100ft and 1500ft. The total effective FATO length would be 1.5T + 1100 to 1500FT. A vertiport designed to these requirements would be required for scheduled service and/or where maximum range was required. It is proposed that the AC indicates a range for the 'FATO + RTOA' of between '1.5T + 1100ft' to '1.5T + 1500ft'.

Reference in the Vertiport Design AC to a *minimum* FATO + RTOA length of '1.5T + 800ft' could be included since such a vertiport would be viable. Below about 1.5T + 800ft, the takeoff weight/payload penalties would be unrealistically large. Even so a vertiport with a total length of 500ft would still often have advantages over the 'minimum VTOL facility' and thus it may be prudent to also mention this in the AC. [Note: These latter dimensions are <u>not</u> indicated in the attached table.]

(c) STOL Private (PPR) / General Aviation:

A rollaway of 400ft will provide considerable benefit and enable takeoff at maximum weight. It can be assumed that takeoff is started at or near the end of the TLOF, so a total TLOF length of 0.5T + 400ft would be required. For a PPR facility only this rollaway (400ft) would need to be considered

To provide 'stopping' distance for an 'abort takeoff procedure' prior to 'liftoff,' data indicates a need for an additional 250ft or total of 650ft. Thus a FATO of 1T + 650ft would be required. This would be considered applicable to a General Aviation facility. [This would not, however provide a full CAT A/Class 1 capability – see STOL Transport below.]

Boeing has previously stated that for the CTR2000 (V-22 size CTR) a STOL length of 600ft, instead of 400ft, and a total length of 800ft in place of 650ft, would be required. As a consequence it suggested that for vertiports to handle larger CTRs, these values should be considered.

(c) STOL Transport:

To provide space to accommodate a 'rejected takeoff' of between 1100ft to 1500ft, similar to the VTOL Transport facility would be required in addition to the rollaway. As a consequence a 'total length' for the FATO of between 1T plus 1500ft and 1900ft would be required for such a facility.

5. IFR VERTIPORTS

(a) NON-PRECISION Vertiports:

Here it is proposed that, as for heliports, no additional ground space is required.

(b) PRECISION IFR Vertiports:

There is little guidance at the present time and thus industry can not offer any specific additional guidance. Vertiports design to include RTOAs should however, based on available information to, be adequate to cover the requirements for 'full IFR precision operations.'

7. TAKEOFF AND LANDING (TOUCH DOWN AREAS)

NASA studies have indicated that there is approximately an equal chance to "under-shoot" or "over-shoot" on landing and thus the *aiming point* or *landing target* should be located in the center of any 'elongated FATO.' Similar proposals have been made in the past for heliports designed for Cat A/Class 1 'schedule operation.' In the case of the 'takeoff pad' this is best sited at the 'end of an elongated FATO' to provide takeoff into wind. It is suggested therefore that consideration is given to separate 'Touch Down' and 'Landing Pads'. This is illustrated in the attached Figure. There is no readily available terminology for designating these 'pads' but these could be called TD (Touch Down) and LO (liftoff) pads. Alternatively the 'pads' could be simply called TOP (takeoff pad) or TOA (takeoff area) and LOP (liftoff pad) or LA (landing area).

8. SAFETY ZONE/TAXIWAYS:

Since the CTR will act like a helicopter in the 'heliport area,' and taxi on wheels it is proposed that the same concept as applied for General Aviation Heliports and Transport Heliports are applied. Thus for GA 1/3 T or 20 ft and for Transport 1/3 T or 30 ft where 'T' is the proprotor tip-to-proprotor tip distance (60ft for BA609) should apply.

9. VFR AIRSPACE:

In general airspace (approach /departure surfaces) being developed for helicopters should apply, the CTR will however have a more rapid takeoff and be able to fly a 6 degrees or more steeper descent. Such vehicles will, however, also use 3 degree for landing, particularly at airports. Thus the minimum slope to be considered should be 3 degrees. For environmental reasons 6 degrees or more, or special *noise abatement procedures*, will be used.

Takeoff and landing profiles are being developed/calculated by Bell Helicopter Textron to guide the choice of the *close-in* airspace 'slopes.'

10. SAFETY ZONES/PROTECTION ZONES

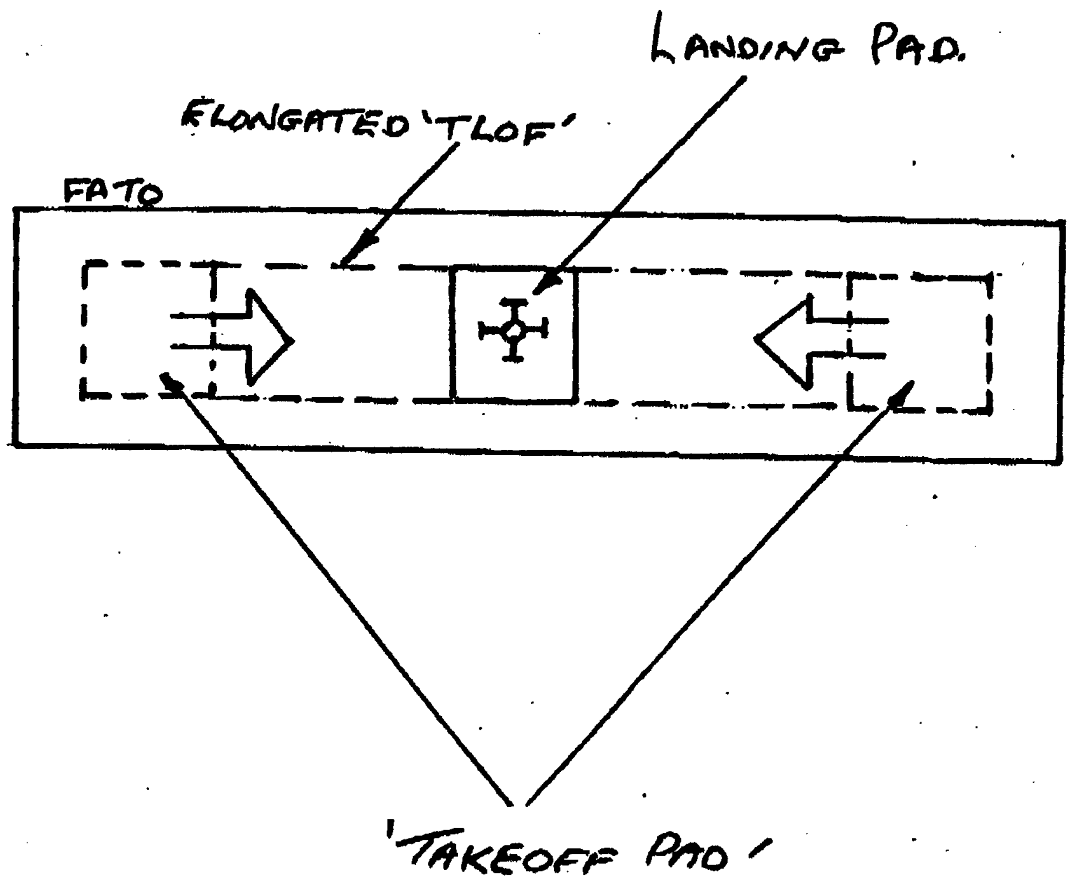
For VTOL facilities safety and protection zones the same dimensions as used for heliports should apply. For STOL the same can be recommended but it is likely that the FAA will propose that 'airport values', typically longer, are more appropriate. This should not be the case since even if a STOL takeoff is used the actual liftoff/takeoff will still be like a helicopter. ICAO and Transport Canada also apply separate 'clearways' in addition to the safety zone. All these issues will need to be addressed; it is proposed initially to support use of the values recommended for heliports.

11. MINIMUM DESIGN DIMENSIONS:

The **minimum dimensions** considered appropriate for a vertiport based on the BA609 characteristics is given in the attached table together with values for a larger V-22 size CTR. Many of these are defined in terms of the CTR proprotor tip-to-proprotor tip
(T-factor) and as a consequence should be applicable to all CTR's. Some dimensions (particularly the TLOF length) are defined in terms of specific distances: since these are a function of power/thrust/weight ratio which is likely to be similar for all CTR's including future vehicles based on the V-22. It is also of interest to note that to, a first order, they are similar to those associated with a modern helicopter designed to meet FAR/JAR Part 29 requirements. The only exception in the 'STOL requirements' which, like an aircraft, will to some extent, be depended on the particular vehicle. As a consequence different STOL rollway lengths are recommended for the 'BA609' type of family of CTR and large V-22 size vehicles. The values quoted for the later are based on information made available previously by Boeing for the CTR2000 – a CTR based on the 'V-22 dynamic system' with a new proprotor.

12. 'T' FACTOR

The new term 'T factor' is introduced in this document to avoid confusion with the 'D factor' (or OL) commonly used for helicopter overall length. This is not a critical issue and D or OW (overall width) could be used.



Proposed Layout: Vertiport with Elongated 'TLOF'

		VERTIPORT DIMENSIONS						
		(VFR AND NON-PRECISION IFR)						
1. WIDTH								
	TLOF	FATO						
	1T	1.5T						
2. LENGTH								
Category	TLOF	FATO	RTOA	Rollway	TOTAL LENGTH FATO+RTOA+Rollwa	Safety Zone	Protection Zone	Remarks - Total Length (excluding Safety/Protection Zone)
ALL CTRs								
VTOL Private (PPR)	1T	1.5T	N/A	N/A	1.5T	1/3T or 20ft	N/A	
VTOL General Aviation	1T	1.5T	N/A	N/A	1.5T	1/3T or 30ft	280ft	
VTOL Transport (Minimum-Short Field Len	1T	1.5T	200ft	N/A	1.5T+200ft	1/3T or 50ft	280ft	FATO + 'Short' RTOA
VTOL Transport - Schedule Service (Maxim	1T	1.5T	1100-1500ft	N/A	1.5T + 1100-1500ft	1/3T or 50ft	400ft	FATO +'Free Field' RTOA
SMALL (BA609) SIZE CTR								
STOL Private (PPR)	0.5T+400ft	1T +400ft	N/A	400ft	1T +400ft	1/3T or 20ft	0	Rollway Distance ONLY
STOL General Aviation	0.5T+400ft	1T + 650ft	250ft*	400ft	1T + 650ft	1/3T or 30ft	280	Rollway + Ground Stopping Distance:No RTOA
STOL Transport	0.5T+400ft	1T + 650ft	1100-1500ft	400ft	1T + 1500-1900ft	1/3T or 50ft	400	Rolleway + RTOA
LARGE (CTR2000) SIZE CTR **								
STOL General Aviation	0.5T+600ft	1T + 800ft	200ft*	600ft	1T + 800ft	1/3T or 30ft	280	Rollway + Ground Stopping Distance:No RTOA
STOL Transport	0.5T+600ft	1T + 800ft	1200-1600ft	600ft	1T + 1800-2200ft	1/3T or 50ft	400	Rollway + RTOA

Assumptions: VTOL - Takeoff initiated from center of TLOF/FATO *Stopping Distance
STOL - Takeoff initiated from end of TLOF

Note: FATO would need to be 'load bearing' to ensure safe rejected takeoffs.

NOTE: **STOL distances/ RTOA for Large (CTR2000) CTR need to be reconfirmed with Boeing

Ref:Vertidim2 (10 July '99)

[FAA Note: At the time this paper was written, these Industry-proposed dimensions were NOT supported with any technical justification. Additional data and analysis will be required before the FAA will be able to support a specific set of recommendations.]

VERTIPORT DESIGN AC REVISION - WHITE PAPER CIVIL TILTROTOR – MANEUVERING AND GROUND TAXI ROTORWASH

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September 1998

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Rotorwash Characteristics

1.0 INTRODUCTION

The effect of rotorwash as it flows horizontally across the ground has been the subject of numerous research efforts since the mid 1960s. The first research efforts focused on studying rotorwash as it applied to helicopters and tiltwing aircraft in military related applications. In more recent years, the tiltrotor concept has been the focus of a majority of this research work. This focus has occurred because the NASA/Bell XV-15 has been a tremendous success as a technology demonstration program and, as a result, the Bell-Boeing V-22 has entered production for the U.S. military. More recently, the Bell-Agusta 609 civil tiltrotor project entered the prototype design phase and deliveries to commercial operators are now expected early in the year 2002.

The purpose of this report is to document recent V-22 rotorwash testing that has been conducted for civil tiltrotor (CTR) applications by the U.S. Navy on behalf of the Federal Aviation Administration (FAA). This research has been focused on obtaining additional data to aid in the planned revision process for the Vertiport Design Advisory (reference 1). These tests have included measurement of rotorwash characteristics while the V-22 was parked on the ground at various levels of rotor power and during ground taxi and air taxi maneuvers. This is the first time that these types of data have been measured on any type of rotorcraft. U.S. Navy personnel at Patuxent River NAS acquired the FAA requested data as an addendum to V-22 rotorwash testing they had already planned (reference 2). This test was focused on measurement of worst case rotorwash characteristics in a stationary hover as it has been traditionally evaluated. Therefore, thanks go out to the combined U.S. Navy/Bell-Boeing V-22 test team. Without their hard work, these data could not have been acquired. Thanks also go out to Bell Helicopter Textron personnel that fly and maintain the XV-15. As a result of their effort, ground taxi power required data were acquired that are representative of a small CTR configuration (such as the Bell-Agusta 609).

2.0 CTR TILTROTOR DATBASE

Three different types of tiltrotor aircraft have been flown to date. The Bell XV-3 (figure 1) was first flown in August 1955. Even though it was tested in the NASA Ames 40x80 wind tunnel as late as 1965, no known hover rotorwash measurements were ever obtained from this aircraft. If the XV-3 had been tested, the low disk loading rotors would not have yielded a strong rotorwash flow field across the surface of the ground.

The Bell XV-15 (figure 2) was designed in the mid 1970s and was first flown on May 3, 1977. This NASA/Army/Navy demonstrator program proved the tiltrotor concept so successfully that the second of the two XV-15 test aircraft is still in use today as a research vehicle. The XV-15 aerodynamic configuration is fully representative of a modern CTR and the Bell-Agusta 609 that is presently in engineering development is almost identical in size and layout (figure 3). The U.S. Navy and NASA conducted a comprehensive examination of the rotorwash characteristics of this aircraft in 1981. The report documenting the results of this test is listed as reference 3. The rotorwash velocity profile data acquired during the test were obtained with an ion-beam anemometer (no moving sensor components) at approximately one-foot increments from 0.5 to 9.0 feet above ground level (AGL). The hovering wheel height for the majority of these data was 25 feet AGL. The quantitative data obtained from this test have been used to verify the results of several analytical prediction efforts and are considered to be high quality test data following numerous detailed reviews. Data from this test are presented in later sections of this report as a basis for reviewing expected Bell-Agusta 609 rotorwash characteristics.

The Bell-Boeing V-22 (figure 4) was designed in the mid 1980s and made its first flight on March 19, 1989. The V-22 is the first production tiltrotor aircraft and is in development for the U.S. Marine Corps and the Air Force. Even though the V-22 is a military aircraft, the configuration is very similar to the 40-passenger CTR configurations proposed to date. The first of two V-22 rotorwash tests was conducted by U.S. Navy personnel in 1990 at Bell's Arlington Flight Research Center and is documented in reference 4. Like the XV-15 test, this test used the ion-beam anemometer but was very limited in scope. Even though velocity profile data were acquired at three rotor heights above the ground, the data were acquired at only one distance from the center of the aircraft (directly in front along the aircraft centerline).

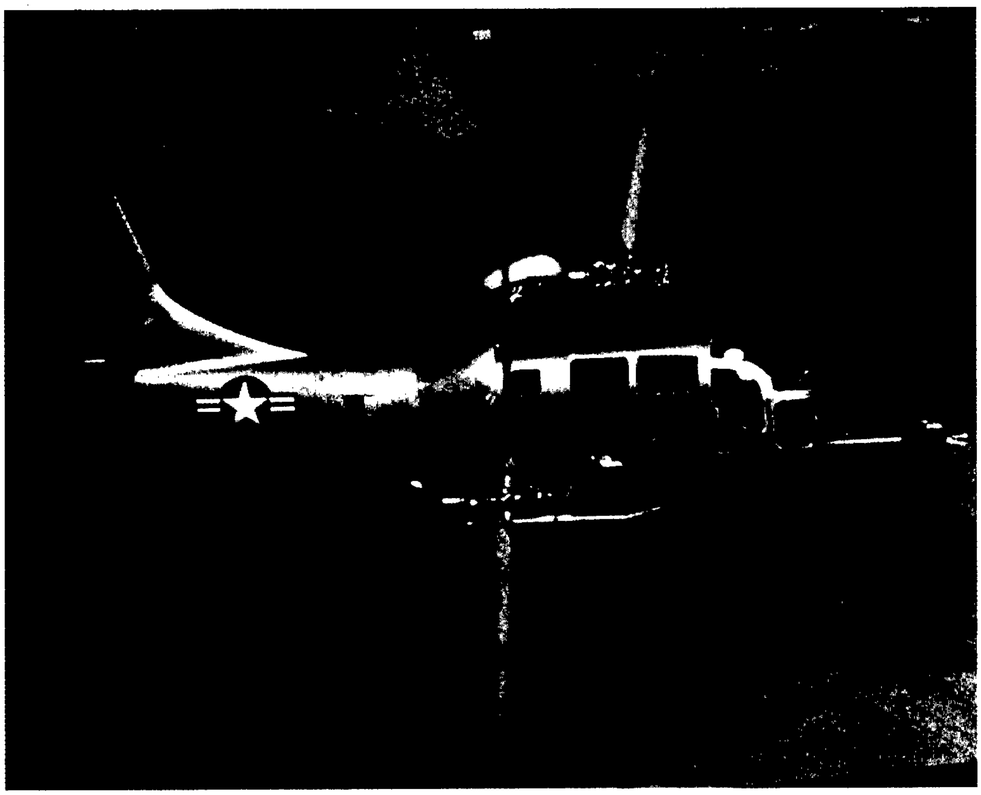


FIGURE 1 BELL XV-3 IN FLIGHT

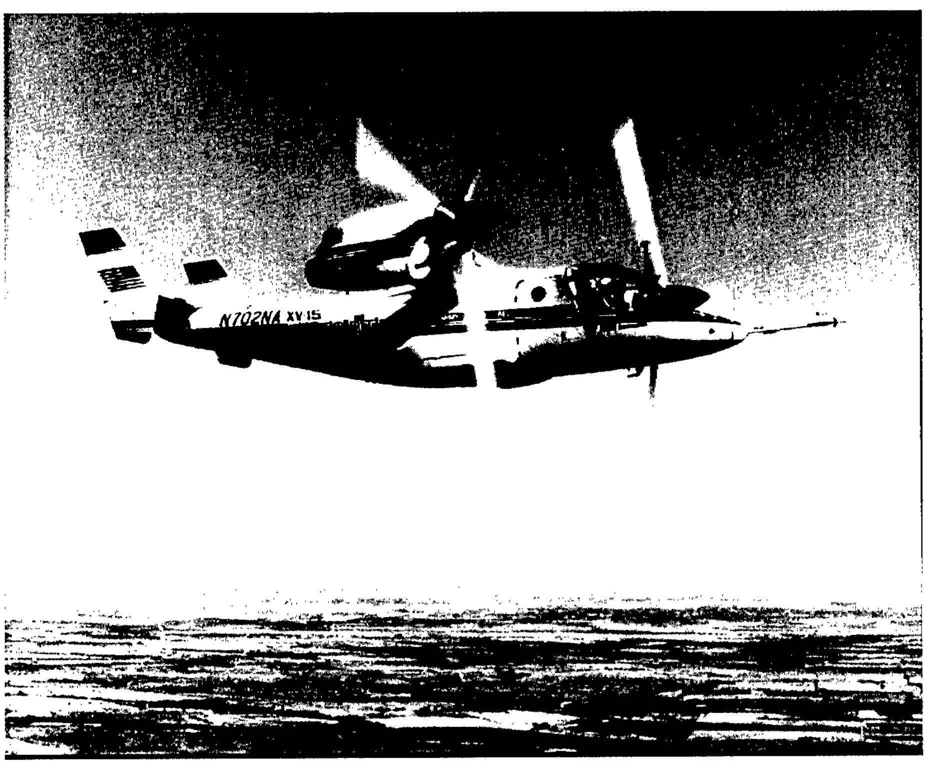


FIGURE 2 BELL XV-15 IN FLIGHT

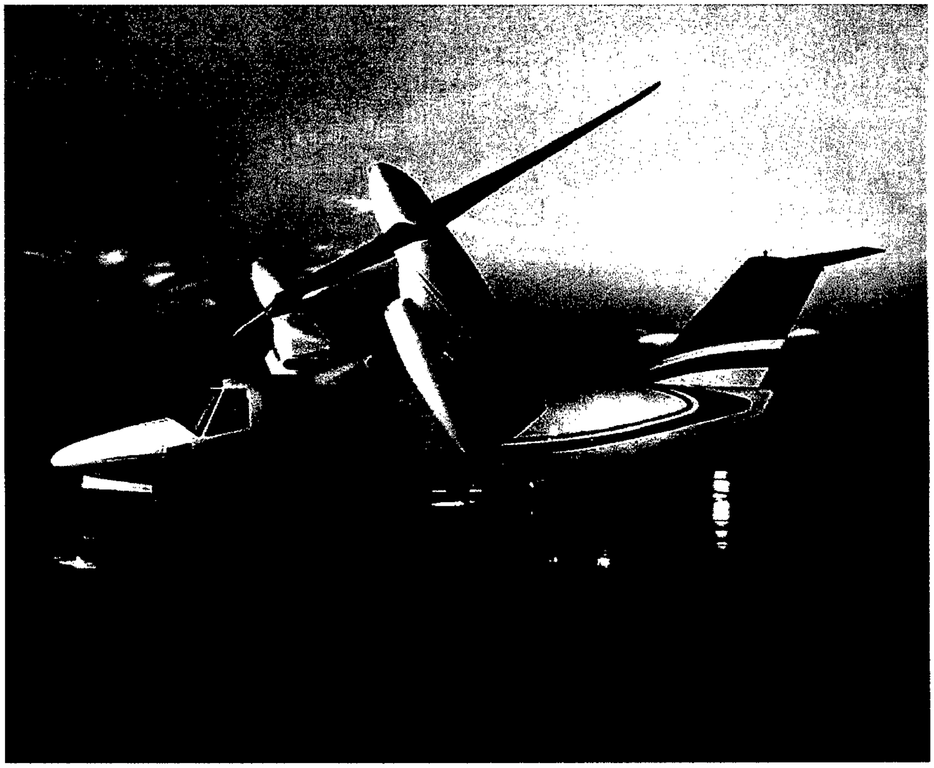


FIGURE 3 BELL-AGUSTA 609 FULL SCALE MOCKUP

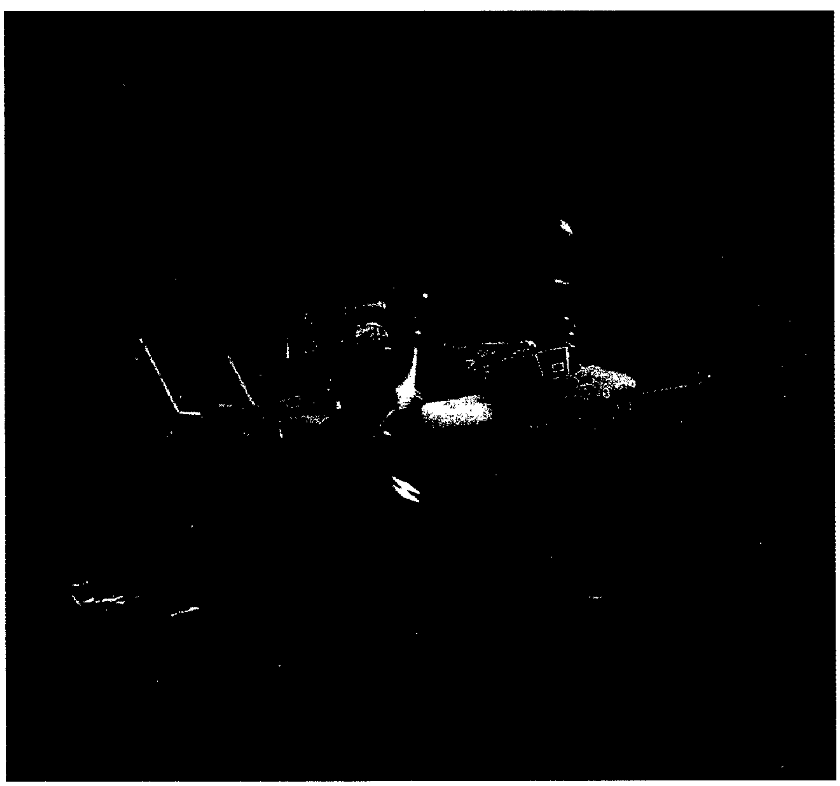


FIGURE 4 BELL-BOEING V-22 IN FLIGHT

The same U.S. Navy personnel have recently concluded the second of the two V-22 tests at Patuxent River NAS in two phases. The first phase was conducted on December 18-19, 1997 and velocity profile data were acquired at three hovering wheel heights (20, 60, and 100 ft AGL) for distances varying from 19 to 156 feet from the center of the aircraft. These data were acquired using a new ultrasonic anemometer manufactured by Gill Instruments, LTD. Results from this test are documented in reference 2 and define the flow field around a hovering V-22 in great detail. These data also supercede the data taken during the first V-22 test in 1990.

The second phase of V-22 testing was conducted on May 15, 1998. This test acquired data for the V-22 while parked on the ground at several power settings, while taxiing on the ramp, and during several air taxi maneuvers. These velocity profile data were acquired to fulfill a data request from the FAA and are the focus of this report. The request was submitted to the U.S. Navy for the purpose of obtaining data to support the development of a new Vertiport Design Advisory document (reference 1). These test data are presented and discussed in section 2 of this report in a context useful for this purpose. Appendix A provides a more complete documentation of the test data in a format useful to researchers interested in the analytical prediction of rotorwash characteristics.

2.1 Hover Rotorwash Characteristics

Historically, all rotorwash velocity profile data have been acquired from hovering rotorcraft in calm winds within approximately three rotor diameters of the ground. It has been assumed that this flight condition represented the worst case scenario. An example of a typical velocity profile in front of a hovering V-22 is presented in figure 5. In most cases this assumption is probably correct and certainly these data are the most useful for validation of analytical prediction methods. In this report, the hover data from both the XV-15 and V-22 tests, references 3 and 2 respectively, are presented only in a summary format. This format is intended to support the process of updating the Vertiport Design Advisory. Researchers interested in the measured velocity profiles from these flight tests should refer to the original test reports (reference 5 also documents the XV-15 data).

Tiltrotor velocity profile data must be acquired along at least one of the aircraft centerline azimuths (0- and the 180-degrees) and one of the azimuths along the line intersecting both rotors (90- or 270-degrees) if the flow field characteristics are to be fully understood. Along the centerline, the rotorwash from both rotors collides and reaches maximum velocity. Perpendicular to this axis, the rotorwash characteristics are similar to those of single rotor helicopters. Due to the mirror image nature of data along these axes, flight test data are usually only acquired out the left side or 270-degree azimuth. This azimuth is chosen because most helicopter data are acquired along this "critical" azimuth since the tail rotor downwash exits this direction.

A rotorwash-generated flow field across the ground plane can be characterized as an unsteady or stochastic yet periodic flow field. Reference 5 provides a detailed explanation of each of the important flow field characteristics. Therefore, time histories of measured profiles must be recorded and analyzed to quantify velocity characteristics that can be used for design purposes. The two most important characteristics are the "mean" and "peak" velocity profiles. The mean velocity profile is constructed from the calculated mean velocities from each measured sensor height. In the figure 5 example, the mean velocities at anemometer heights of 1, 2, 3, 4, 5, and 7 feet were calculated and graphed from simultaneously acquired 5-second time histories. The highest measured mean velocity is 36.2 knots at 1-foot AGL. During flight testing the length of recorded time histories is usually a minimum of 20 seconds and the best 5-second period as determined by several factors is subsequently chosen for reporting purposes.

The peak velocity profile is constructed by graphing the peak velocity measured during the same 5-second time period. The various points defining this velocity profile do not necessarily occur at the same time. Along the velocity profile presented in figure 5, the peak velocity is 72.3 knots at a height of 2-feet AGL. This peak velocity, due to the physics of how rotorwash expands along the ground, is usually measured between 1- and 3-feet AGL.

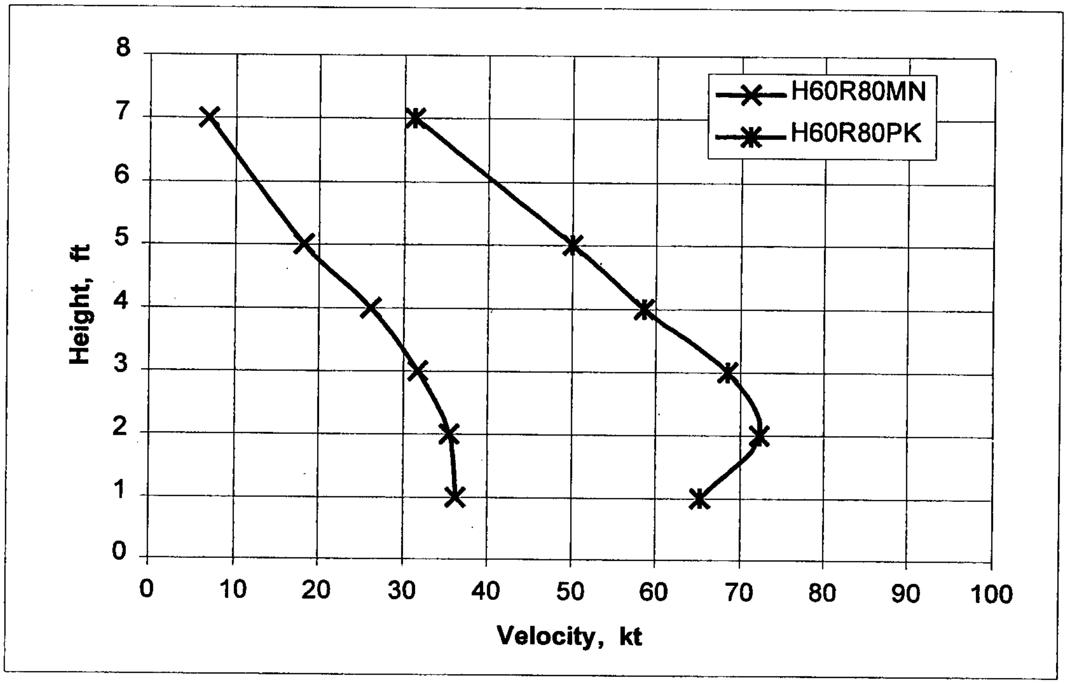


FIGURE 5 V-22 MEAN AND PEAK VELOCITY PROFILES AT A WHEEL HEIGHT OF 60 FT AND A DISTANCE FROM THE CENTER OF THE AIRCRAFT OF 80 FT ALONG THE 270-DEG AZIMUTH

The peak velocity profile is constructed by graphing the peak velocity measured during the same 5-second time period. The various points defining this velocity profile do not necessarily occur at the same time. Along the velocity profile presented in figure 5, the peak velocity is 72.3 knots at a height of 2-feet AGL. This peak velocity, due to the physics of how rotorwash expands along the ground, is usually measured between 1- and 3-feet AGL.

For design purposes, it is important to summarize the mean and peak velocity profile characteristics. This task is accomplished by graphing the largest calculated mean velocity from each profile along with the largest measured peak velocity as a function of the distance from the aircraft center (DFAC). The DFAC distance is zero at the intersection of the aircraft centerline and the line connecting the two rotors. Along the centerline of the aircraft (0- and 180-degree azimuths), the term distance along the interaction plane (DAIP) is often interchangeably used.

Flight test data acquired from both the XV-15 and the V-22 as a function of DAIP are summarized from individual peak velocity profiles in figure 6. These data are presented because they will be required in a later section of this report. Values of wheel height AGL, azimuth of measurement, and rotor speed in percent of normal operating RPM are documented for eight test conditions. The largest measured values of peak velocity for the V-22, approximately 95 knots, are measured at 35 to 45 feet DAIP. Similarly, the largest values for the XV-15, approximately 75 knots, are measured at 25 to 30 feet. As a general rule, these maximum values are approximately one rotor diameter from the aircraft center along the 0- and 180-degree azimuths.

Along the 270-degree azimuth, the decay in measured peak velocity occurs more rapidly with increasing DFAC. Figure 7 documents these data for both the XV-15 and V-22. The largest measured values of peak velocity for the V-22, approximately 95 knots, are measured at 50 to 60 feet DFAC. Correspondingly, the largest values for the XV-15, approximately 65 knots, are measured at 25 to 30 feet. As a general rule, these maximum values are approximately 1.5 rotor radii from the center of the rotor along the 270-degree azimuth.

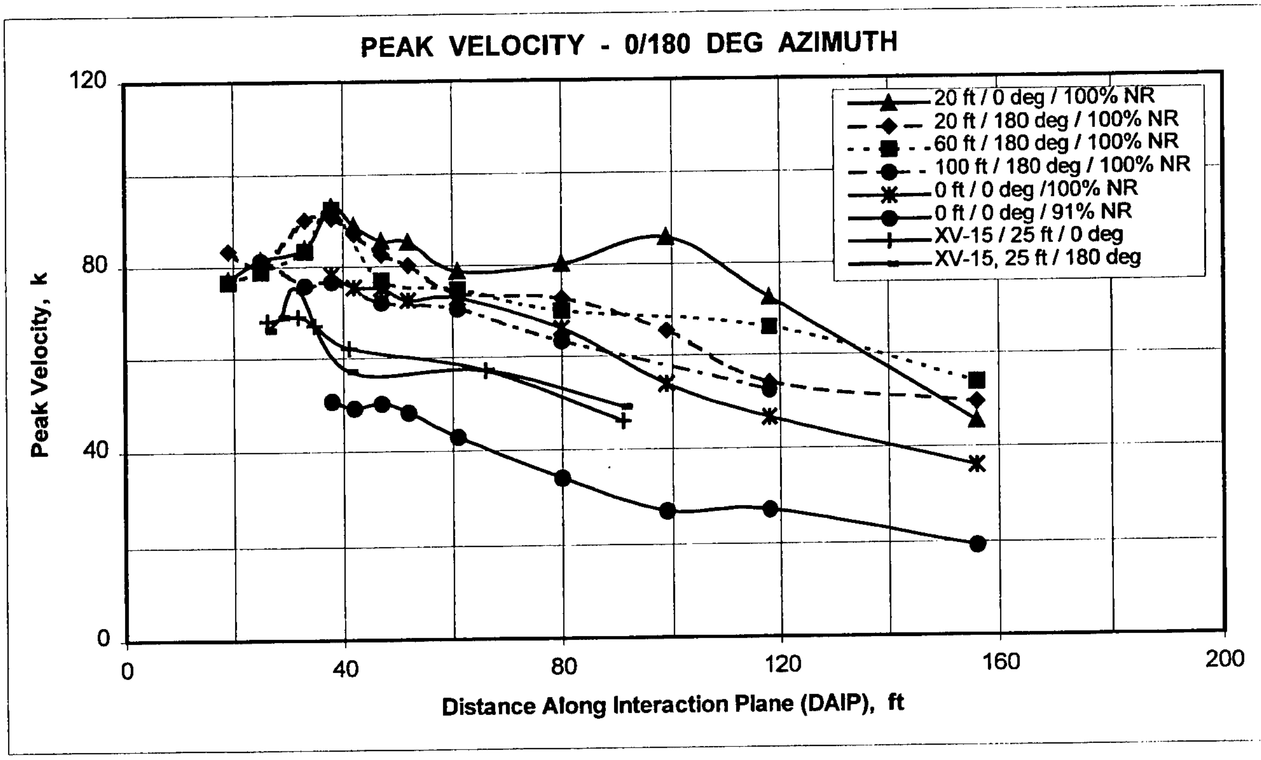


FIGURE 6 MEASURED PEAK VELOCITY AS A FUNCTION OF DISTANCE ALONG THE INTERACTION PLANE (0/180-DEGREE AZIMUTH)

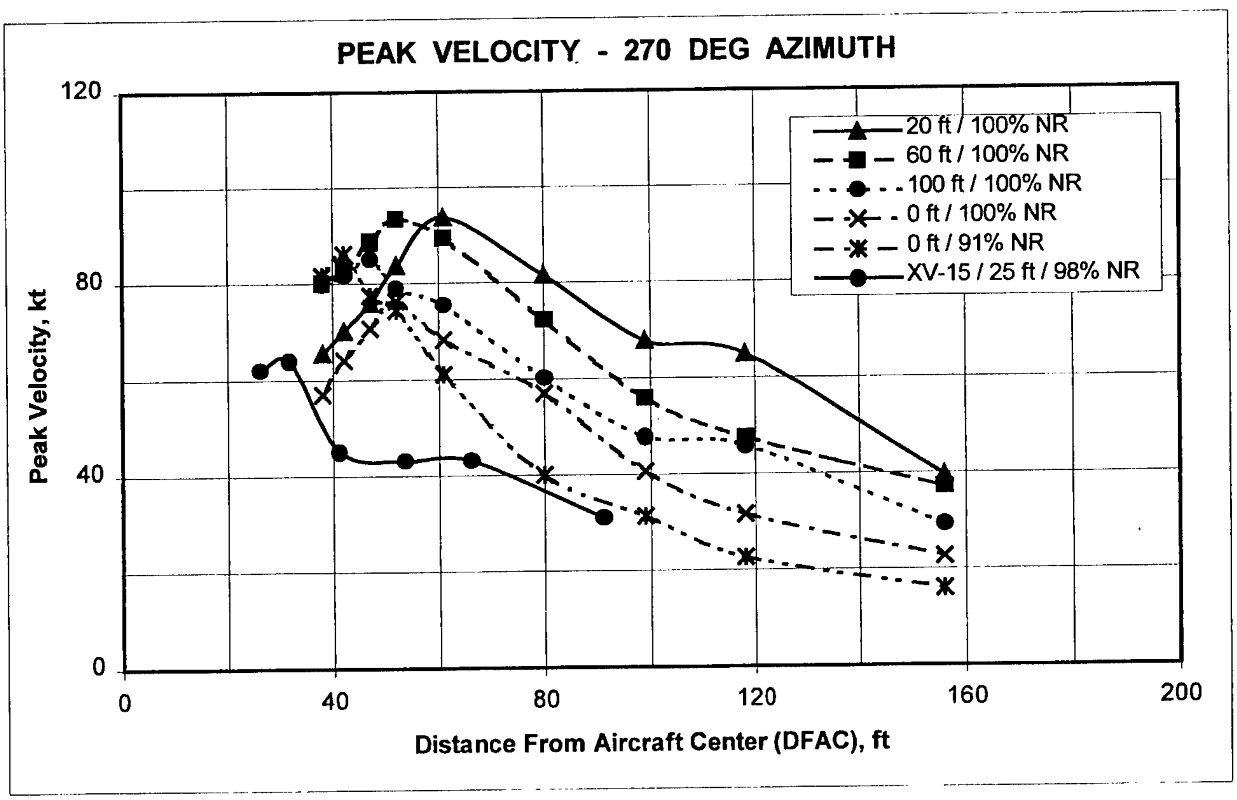


FIGURE 7 MEASURED PEAK VELOCITY AS A FUNCTION OF DISTANCE FROM AIRCRAFT CENTER (270-DEGREE AZIMUTH)

2.2 Maneuvering Rotorwash Characteristics

As stated in the previous section, assumptions have historically been made in acquiring rotorwash data. One of these assumptions is that hover rotorwash data acquired near the maximum gross weight in close proximity to the ground in calm air represents a reasonable worst case scenario. Unfortunately, minimal data have been acquired over the years to verify this assumption. During the last decade a concern has been discussed that crosswinds in the 5 to 10 knot range as well as certain in-ground effect (IGE) maneuvers might significantly increase peak rotorwash velocities along certain azimuths when compared to hover velocities. Therefore, the FAA test plan for the second phase of the V-22 test requested that rotorwash data be acquired for two air taxi maneuvers as described in table 1. It was hoped that data from these maneuvers might provide guidance as to the significance of air taxi maneuvering on peak rotorwash velocities for future testing.

TABLE 1 V-22 AIR TAXI MANEUVER TEST CONDITIONS

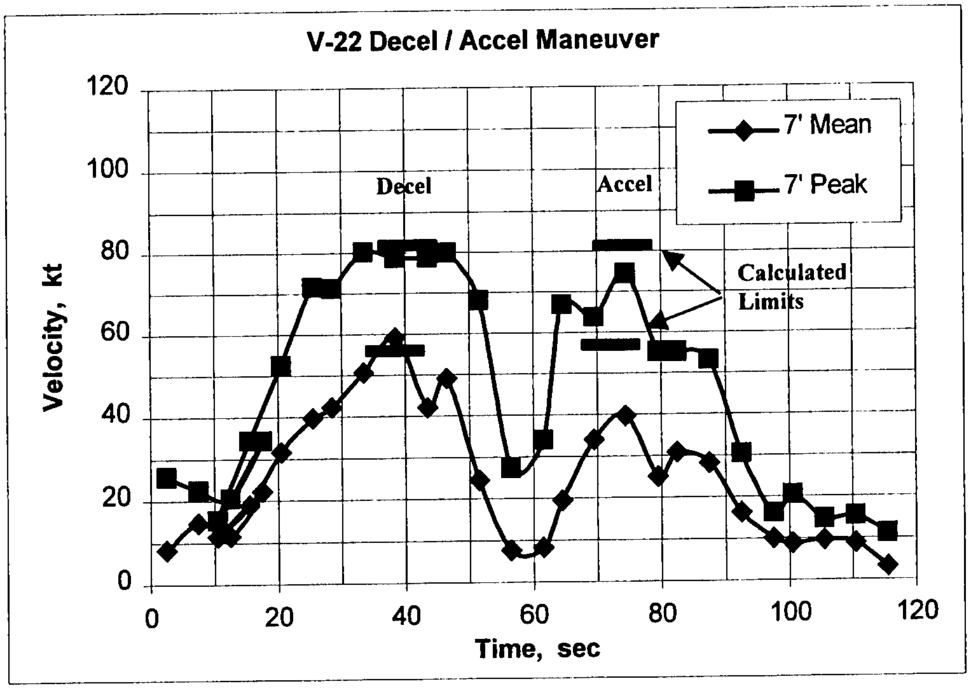
Azimuth,deg	Wheel Height, ft	Type Of Maneuver
0	20	Deceleration at air taxi aggressiveness to a hover. Anemometers located in a fixed position at a DFAC of approximately 61 feet (2R) directly in front of the aircraft along the centerline (while in hover).
180	20	Accel at air taxi aggressiveness from a hover. Anemometers located in a fixed position at a DFAC of approximately 61 feet (2R) directly behind the aircraft along the centerline (while in hover).

The first air taxi maneuver executed during the test was a deceleration to a hover. It was hypothesized that the peak rotorwash velocities would probably occur just as the aircraft reached zero forward velocity. The peak velocity along the 0-degree azimuth would be the result of the increased thrust required to arrest the forward motion and the nose high pitch attitude required to obtain a decelerating thrust vector. Likewise, after the V-22 made a 180-degree hover turn, the second acceleration maneuver would require increased thrust and a nose down pitch attitude to initiate forward motion. Therefore, the peak velocity along the 180-degree azimuth was hypothesized to occur as the V-22 departed the hover position.

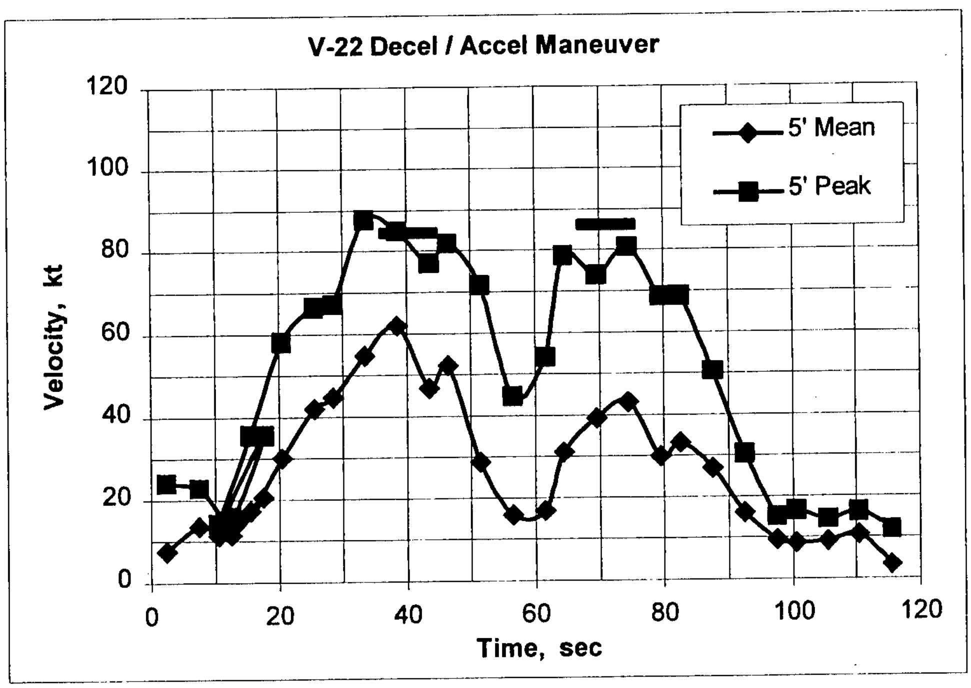
Following an analysis of the aircraft data, it was determined that the peak nose up pitch attitude was +6 degrees during the deceleration and the peak nose down attitude was -5 degrees during the acceleration. Additional details for both maneuvers are provided in Appendix A. Graphs of the peak rotorwash values measured during the maneuvers are presented in figure 8 for anemometer heights of 1, 3, 5, and 7 feet AGL. These time histories were produced by dividing the maneuvers into 5-second segments, calculating the mean velocity, extracting the measured peak velocity, and graphing each segment as a single data point at the elapsed time midway through the segment. Anemometers at 2 and 4 feet AGL were not functional during phase II testing.

Analysis of the two maneuvers reveals several interesting observations. First, it appears that both the peak and mean velocities generated during the deceleration maneuver slightly exceed the velocities generated during the acceleration (it should be obvious with only two maneuvers that this observation cannot be proved). The possible exception to this statement occurs at the one-foot anemometer position. However, a detailed analysis of the time segment plotted at 64 seconds reveals that the measured peak velocity of 114 knots is a velocity spike that is not recorded at the other three anemometer locations. Therefore, the velocities generated at this height could be considered approximately equal.

The second observation is that the maneuver peak velocities are, at most, only 5 to 10 percent higher than the peak velocities measured in hover in reference 2 at 52 to 80 feet. This small increase is within the typical scatter of measured data when repeat data points are acquired. Also, if the measured test data are corrected by the increased thrust values required to maintain altitude at the measured peak nose up and nose down pitch attitudes, then the rotorwash values are very close. The analytically corrected values are represented thick horizontal bars placed on the graphs. These corrected values were obtained using the ROTWASH program described in reference 5.

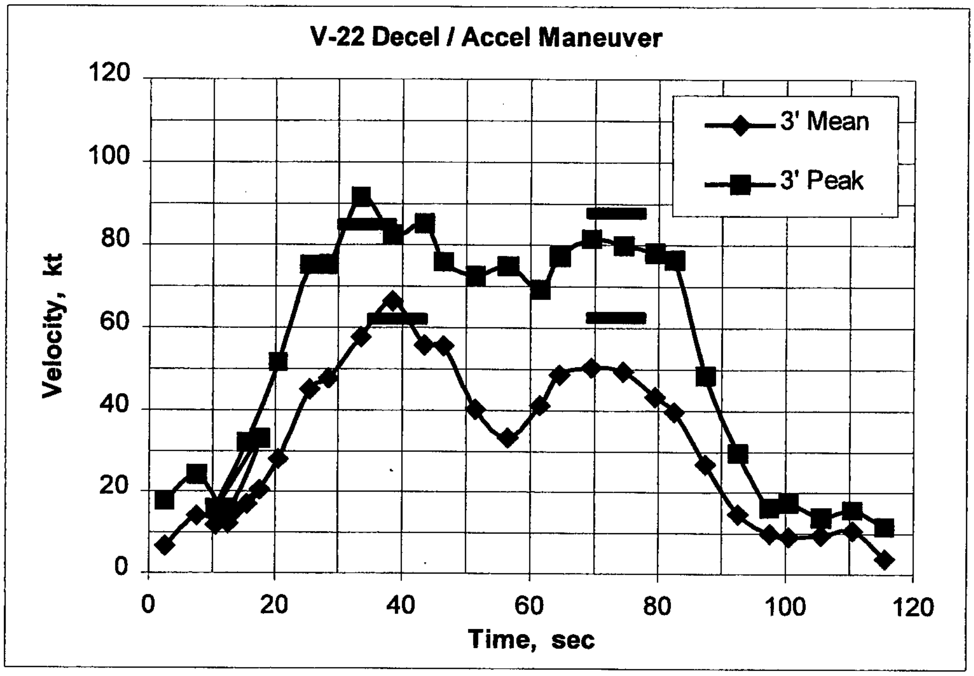


(a) Data at 7-feet AGL

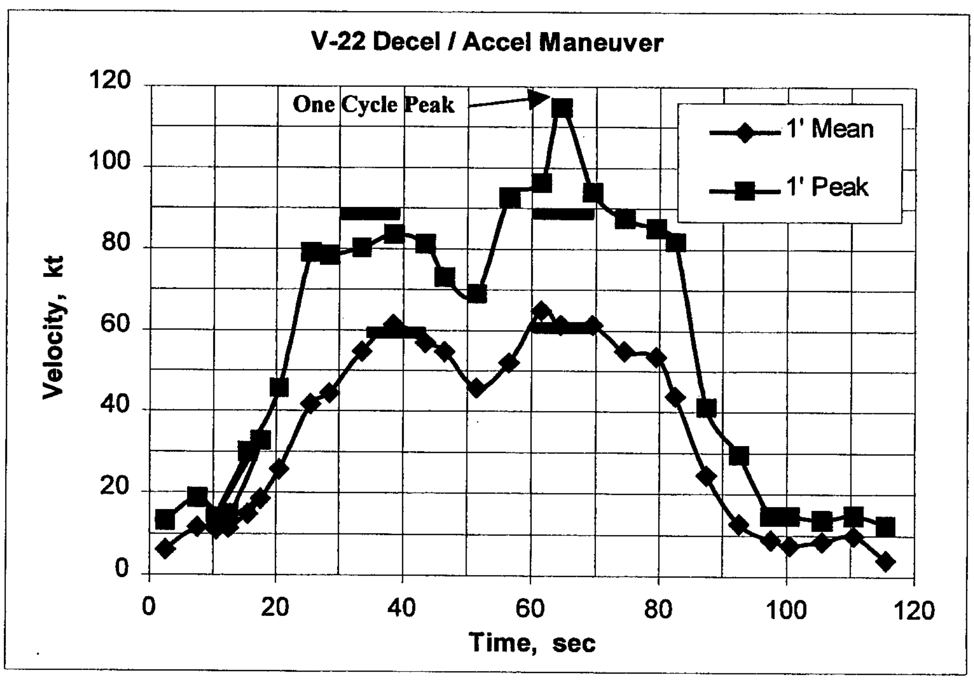


(b) Data at 5-feet AGL

FIGURE 8 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 0- AND 180-DEGREE AZIMUTHS DURING AIR TAXI DECELERATION AND ACCELERATION MANEUVERS



(c) Data at 3-feet AGL



(d) Data at 1-feet AGL

FIGURE 8 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 0- AND 180-DEGREE AZIMUTHS DURING AIR TAXI DECELERATION AND ACCELERATION MANEUVERS (CONCLUDED)

The above observations logically lead to several preliminary conclusions since the data sample is limited. One conclusion is that normal pilot aggressiveness during air taxi does not generate rotorwash peak velocities substantially greater than those measured in hover in calm air. This conclusion somewhat substantiates the discussed historical assumption. A second conclusion is that a simple correction to measured test data (or calculated data) by the thrust level required to maintain level flight appears to closely match test data. This conclusion provides a level of confidence that air taxi rotorwash velocities can be approximated in the future through simulated maneuvers. These simulated maneuvers would be composed of a series of calculated hover data points that are corrected as a function of pitch attitude so as to maintain the required thrust for level flight.

2.3 Ground Taxi Rotorwash Characteristics

Since tiltrotor aircraft are designed for speeds between 300 and 400 knots, they must incorporate wheeled landing gear to minimize drag. Therefore, in most instances a tiltrotor will ground taxi from a landing area to the ramp and terminal areas of both airports and vertiports. Use of ground taxiing provides numerous benefits. It significantly reduces the effect of rotorwash and engine exhaust on the landing surface and surrounding area, reduces fuel consumption and aircraft maintenance costs, and provides increased operational safety. However, the landing and ramp environments must still be sized for the reduced rotorwash velocities generated by large tiltrotors.

In areas where a tiltrotor lifts off or lands, either vertically or in a short takeoff and landing (STOL) mode, the area must be sized and laid out for the effects of rotorwash as generated in a low altitude hover since this is the critical scenario. The data that have been referenced and discussed in the previous section should be used for this design task. Taxi rotorwash velocity data should be used in the design of the remainder of the facility. However, historically a problem has existed in that researchers have never measured rotorwash velocity data for this non-critical phase of operation. Therefore, any design decisions have had to be based on calculated rotorwash velocities.

When calculating ground taxi rotorwash velocities, rotor thrust is the key parameter that must be quantified. When in hover, rotor thrust is easy to determine because it must be equal to gross weight plus the "extra" rotor thrust required to overcome the download generated by the rotorwash impacting the upper surface of the wing. This value of rotor thrust is approximately 1.1 times the gross weight. When taxing on the ground, it is much harder to estimate thrust since gross weight, nacelle angle, tire friction, taxi speed, ambient weather condition, and pilot technique all contributes to the rotor thrust the pilot indirectly selects by moving the power lever. Therefore, the FAA test plan for the second phase of the V-22 test requested that rotorwash data be acquired for ground taxi. The purpose of these data would be to validate calculation procedures for future use.

Initially, V-22 velocity profile data were acquired at various DFAC, azimuth positions, and rotor thrust levels while the aircraft was parked. Table 2 describes this phase of the test. Subsequently, the V-22 was maneuvered about the ramp area and data were acquired from a fixed anemometer location. Table 3 describes the maneuvers.

TABLE 2 V-22 GROUND TAXI STATIC TEST CONDITIONS

Azimuth, deg	Rotor RPM, %	Estimated Total Rotor Thrust, lb	Distance From Aircraft Center (DFAC), ft
0	100	33,810	38, 42, 47, 52, 61, 80, 99, 118, 156
0	91	9,950	38, 42, 47, 52, 61, 80, 99, 118, 156
270	100	22,150	38, 42, 47, 52, 61, 80, 99, 118, 156
270	91	10,400	38, 42, 47, 52, 61, 80, 99, 118, 156

The velocity profile data acquired at each anemometer location in Table 2 are summarized in the previously presented Figures 6 and 7. Details of these velocity profiles at each DFAC location as a function of anemometer height (AGL) are provided in Appendix A. As can be observed, peak profile velocities are significantly less than those measured in hover. In three of the four cases evaluated, peak velocities along the profile are reduced to less than 40 knots at a DFAC of 100 feet. In the case where rotor thrust is near a takeoff value at over 33000 pounds, the peak velocities are near the 20-foot hover values as would be hoped. However, it must be noted that this level of thrust is considerably in excess of the value required to ground taxi.

Estimated values of rotor thrust on the ground are also noted in Table 2. These values were obtained by analysis of rotor power required data using measured V-22 rotor test stand thrust and power data documented in reference 6. These data are corrected for ground effect and atmospheric conditions and will be required by researchers wanting to correlate the measured data with data calculated by analytical methods.

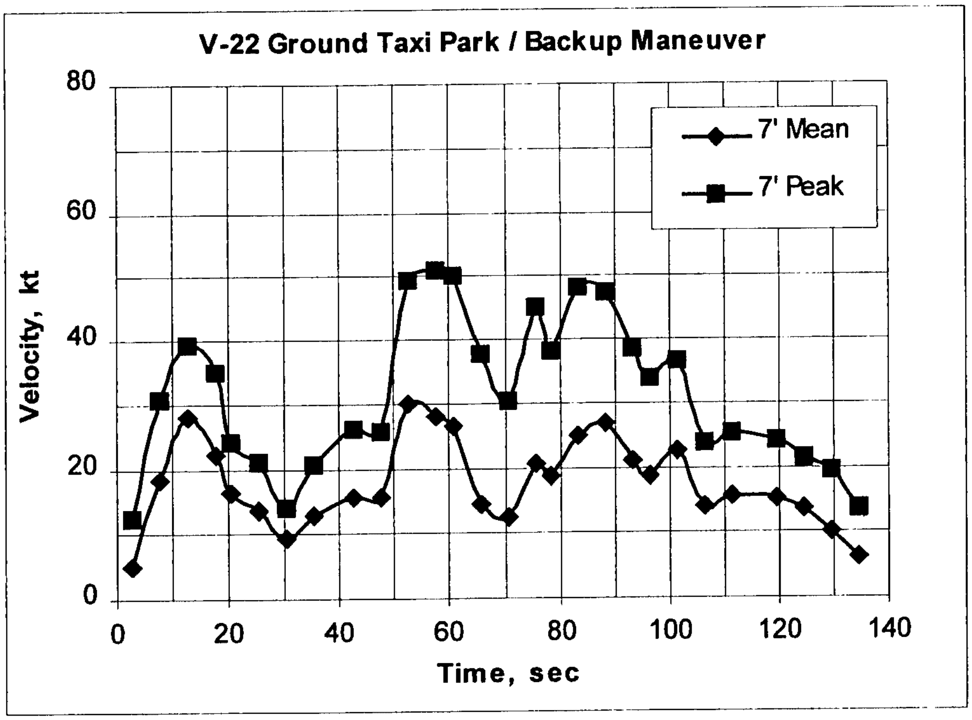
Ground maneuver data as outlined in Table 3 are documented in Figures 9 and 10. The deceleration maneuver is intended to be a simulation of a CTR approaching and parking at a terminal passenger gate. This maneuver occurs between 50 and 65 seconds in Figure 9. The acceleration maneuver is intended to be a simulation of a CTR making a power-back maneuver from a gate in much the same way that an airliner with thrust reversers can power-back from a passenger gate. This maneuver occurs between 70 and 90 seconds in the same figure. Peak velocities measured during the two maneuvers do not indicate any unusual transient behavior. In fact, considering the slightly different power levels, the measured velocities are close in value to those measured at the same distance during the static testing outlined in Table 2.

TABLE 3 V-22 GROUND TAXI MANEUVER TEST CONDITIONS

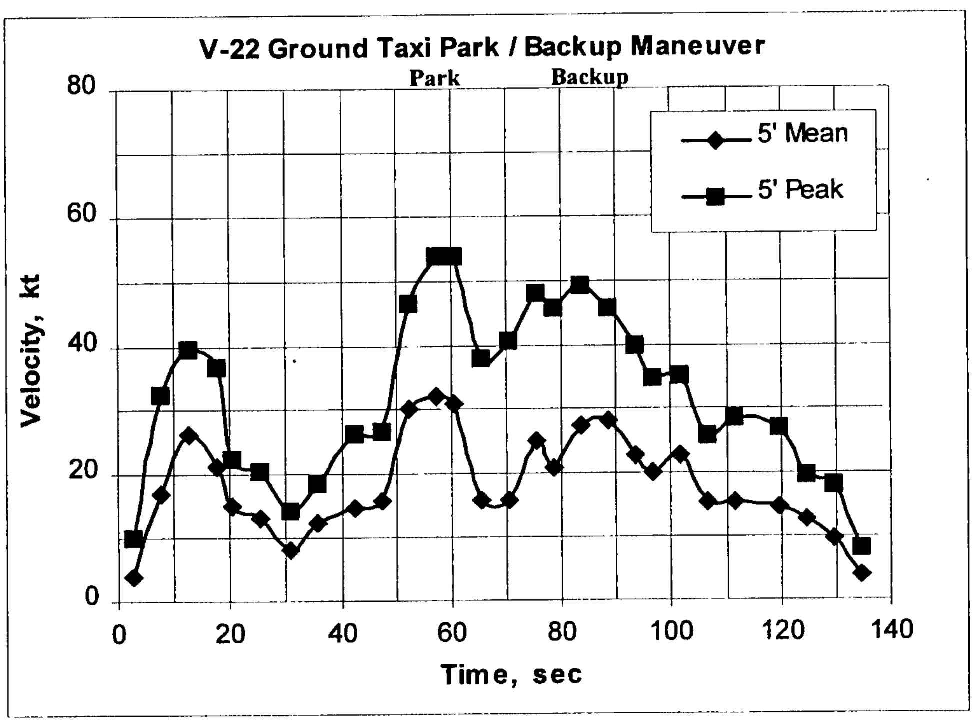
Azimuth,deg	Estimated Total Rotor Thrust, lb	Type Of Ground Taxi Maneuver
0	12,970	Deceleration from ground taxi to a parked position. Anemometers located in a fixed position at a DFAC of approximately 61 feet (2R) directly in front of the aircraft along the centerline (while parked).
0	10,440	Acceleration backwards from a parked position. Anemometers located in a fixed position at a DFAC of approximately 61 feet (2R) directly in front of the aircraft along the centerline (while parked).
270	11,040	Constant speed taxi turn of 180 degrees. Anemometers located at a DFAC of approx. 61 feet at the 90 degree point in the turn (along the line running outward from the aircraft center through the center of the left rotor hub, azimuth of 270 degrees).

The 180-degree turn maneuver was evaluated to obtain velocity data in close proximity to a tiltrotor as it "passed by" a fixed location. The turn component was included because both XV-15 time history data and pilot commentary indicate that power is usually increased during a sharp turn to better maintain ground velocity and aid in turning the nose wheel if power steering is not available (V-22s have nose wheel power steering. The XV-15 and the proposed Bell-Agusta 609 have a simple castoring nose wheel design.) Results from this time history indicate a maximum of 60 to 70 knots at approximately 61 feet. Even though the exact minimum distance to the anemometers could not be measured, these data also compare closely with the measured static data.

Even though these ground taxi data are limited, they confirm a fundamental assumption about the approximate thrust and power levels required for a tiltrotor to ground taxi. The importance of determining a guideline for ground taxi exists because rotor thrust cannot be directly measured on rotorcraft. Thrust can only be measured on a rotor test stand due to the equipment that is required. In contrast, rotor power required is almost always measured on tiltrotor aircraft. Therefore, by measuring power it is possible to estimate thrust using test stand data. The thrust

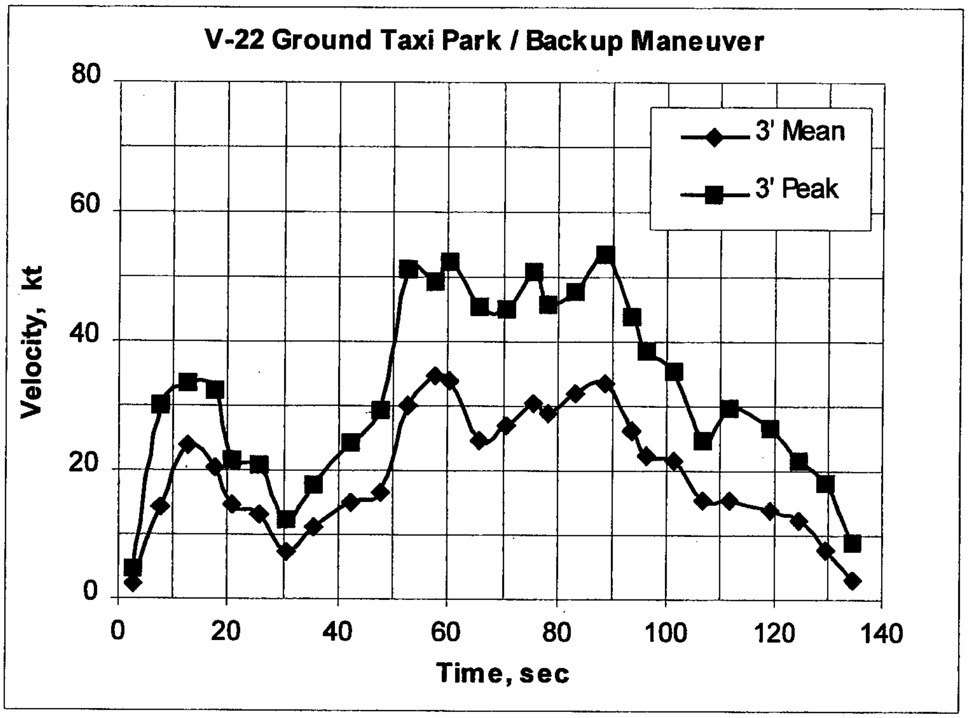


(a) Data at 7-feet AGL

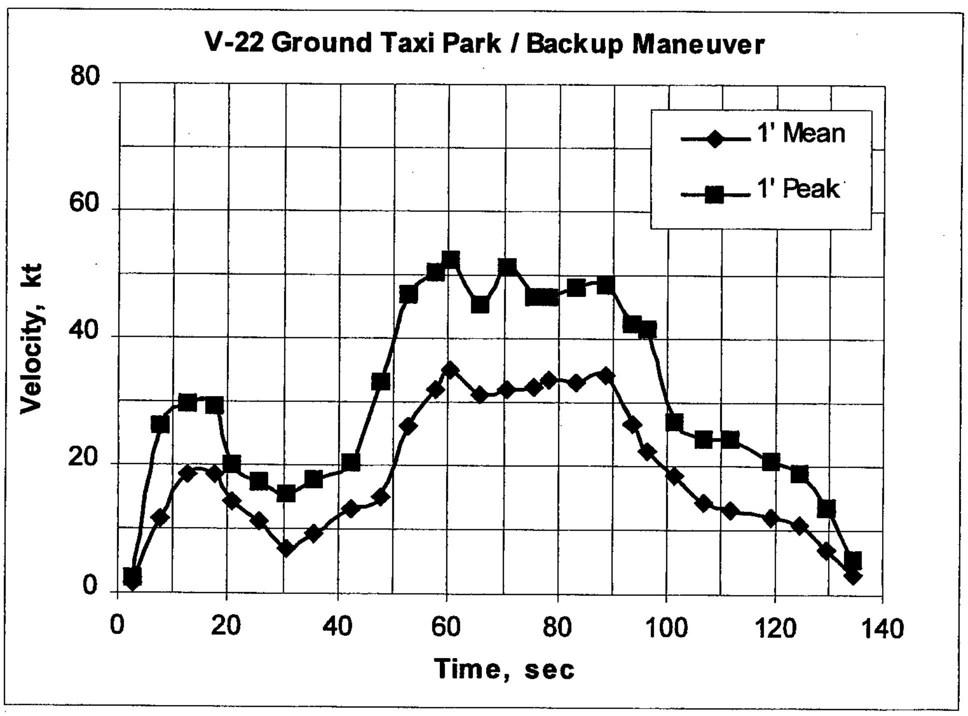


(b) Data at 5-feet AGL

FIGURE 9 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 0-DEGREE AZIMUTH DURING GROUND TAXI PARK AND BACKUP MANEUVERS

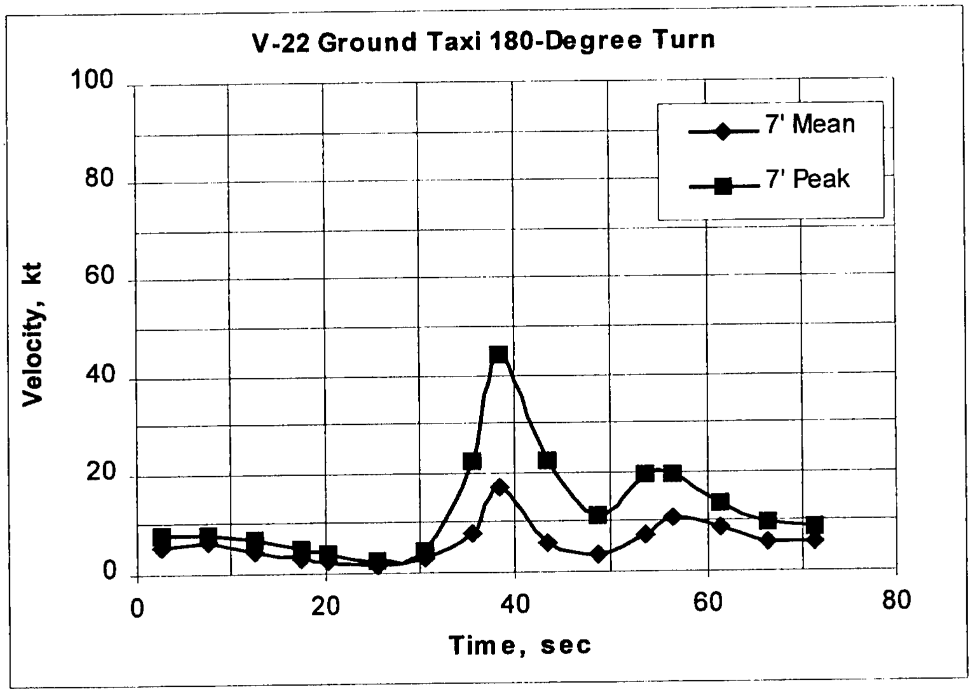


(c) Data at 3-feet AGL

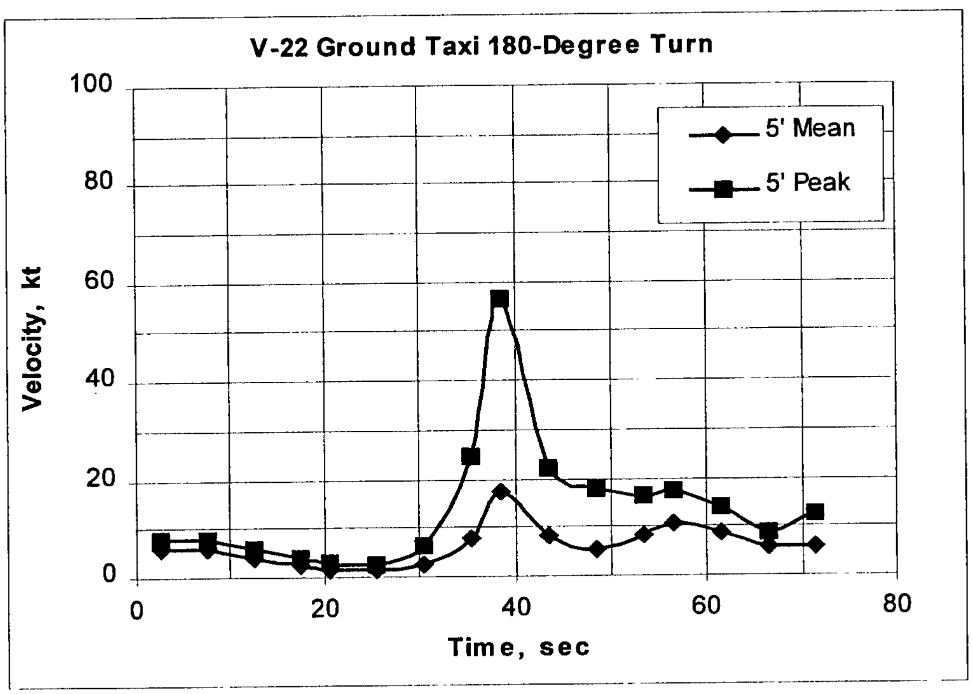


(d) Data at 1-feet AGL

FIGURE 9 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 0-DEGREE AZIMUTH DURING GROUND TAXI PARK AND BACKUP MANEUVERS (CONCLUDED)

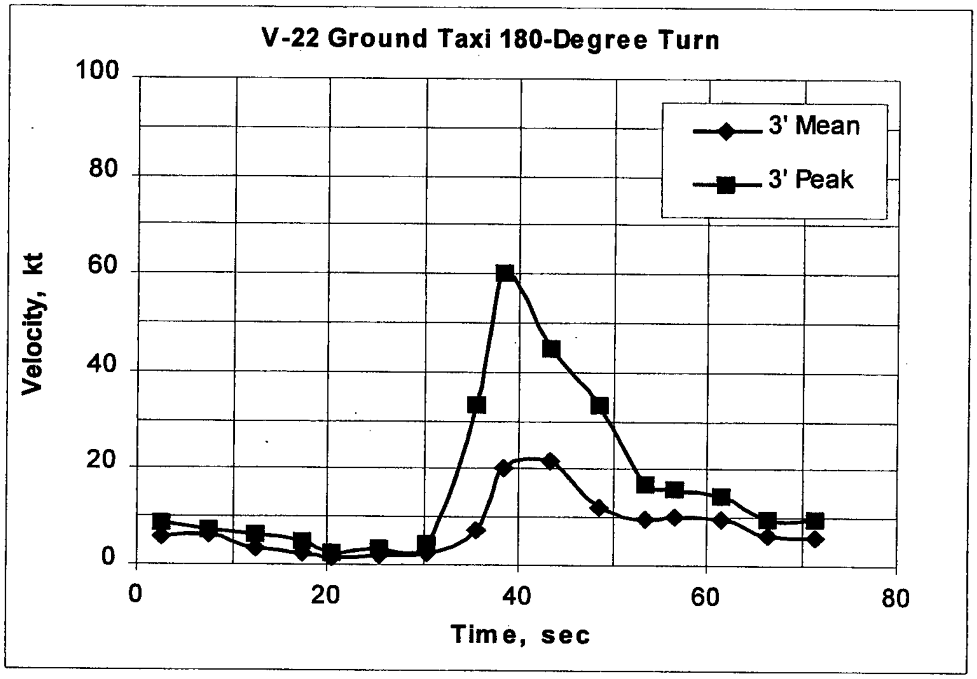


(a) Data at 7-feet AGL

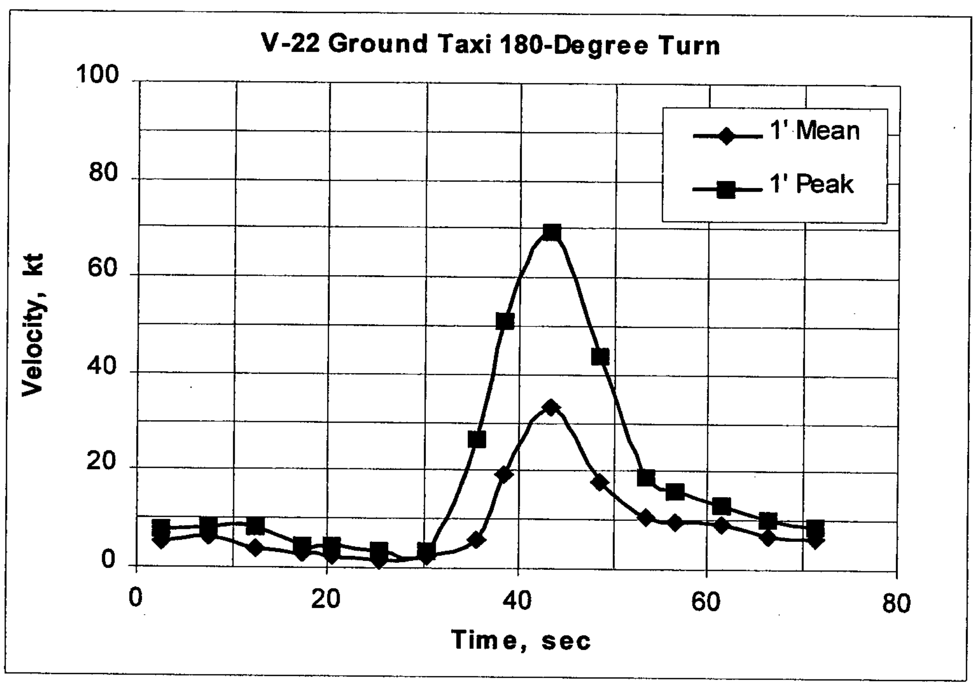


(b) Data at 5-feet AGL

FIGURE 10 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 270-DEGREE AZIMUTH DURING A GROUND TAXI 180-DEGREE TURN MANEUVER



(c) Data at 3-feet AGL



(d) Data at 1-feet AGL

FIGURE 10 MEAN AND PEAK VELOCITIES MEASURED ALONG THE 270-DEGREE AZIMUTH DURING A GROUND TAXI 180-DEGREE TURN MANEUVER (CONCLUDED)

value can then be utilized to calculate rotorwash velocities during taxi if the velocities are not directly measured. The range in values of average power measured during the three V-22 ground taxi maneuvers is 650 to 730 SHP per rotor. On three hovering records prior to these ground maneuvers, the average rotor power required varied from 3490 to 3700 SHP per rotor. These data indicate that the ratio of ground taxi to hover power is approximately 20 percent. To further confirm these data, a much larger database of values was compiled for two other V-22 aircraft and the XV-15. Power ratio data for the V-22 varied from 23 to 27 percent and XV-15 values approximated 28 percent. Collectively, these data indicate a high level of confidence in the statement that an upper limit for this ratio is probably 30 percent. This knowledge will be used in a later section to estimate personnel overturning force data and summarize results on potential rotorwash hazards generated by the various sizes of tiltrotor aircraft.

2.4 Rotorwash Effects on CTR Operations

Rotorwash has many different types of effects on the environment that rotorcraft operate within, both on the ground as well as airborne. Types of effects that have been investigated in reference 5 that apply to this environment include:

1. overturning force/moment effects on personnel,
2. effects on other nearby rotorcraft,
3. effects on fixed-wing aircraft,
4. wake vortex effects on trailing rotorcraft/aircraft,
5. effects on structures (i.e. buildings),
6. effects on ground vehicles,
7. hazards involving entrained objects and debris, and
8. rotorwash-generated particulate clouds.

In this report, our interest focuses on these effects in the context of the immediate vertiport/airport environment. This simplifies the task in that item 4 is expected to have minimal application and item 8, while important, is more of an air traffic control related issue. The remaining items can then be broken down into two groups or subsets for general discussion. These two groups are the titles of the following subsections.

2.4.1 General Rotorwash Effects

In initiating discussion on general effects, it is important to briefly review previous work. Reference 5, as based on the review of a large volume of mishap data, states: "The majority of rotorwash related mishaps can be avoided if separation distances are maintained so that impacting rotorwash generated velocities do not exceed 30 to 40 knots across the ground." The word "majority" and the concept of a "velocity range" are both very important in this statement. The hazard data base is composed of numerous incidents that have both occurred and been reported. Also, most of these incidents were reported with minimal supporting detail data. Therefore, when analyses are conducted using fundamental engineering principles and available flight test data to better understand the details, only a "range of probable velocities" can be assumed to have been present when any specific incident occurred (no direct velocity measurements exist). If a large number of these incidents are investigated, then trends appear in that certain types of incidents only occur when specific calculated "velocity ranges" are exceeded. The velocity range of "30 to 40 knots" is simply the lowest velocity range that is calculated for most types of reported incidents. In the context of this report, when the 40 knot upper limit value is exceeded it is considered important for comparison purposes. The simple use of this specific value (or 30 knots) for vertiport design is inappropriate. If design decisions are to be made, then certain safety factors involved with the tiltrotor configuration, ambient wind, and vertiport layout must also be discussed in conjunction with the selection of either 30 or 40 knots. This subject is beyond the scope of this report and the reader is referred to reference 5 if vertiport design issues are the focus of the discussion.

Referring again to the quote from reference 5: "The majority of rotorwash related mishaps can be avoided if separation distances are maintained so that impacting rotorwash generated velocities do not exceed 30 to 40 knots across the ground." This statement also makes common sense in that, in our everyday lives, we must begin to take precautions with personal property when ambient winds reach the 30 to 40 knot velocity threshold. Therefore, by

simply referring back to Figures 6 and 7, it is possible to begin to quantify the DIAP or DFAC values that become the critical separation distances for both large and small CTR size classes.

When comparing V-22 hovering data with the similarly dimensioned Sikorsky CH-53E data from reference 8 (data included in reference 5), it can be observed that the critical separation distances (peak velocity < 40 knots) for these two aircraft are very close as would be expected. In the case of the V-22 data in Figures 6 and 7, the critical distances are approximately 180+ feet (0/180-degree azimuths) and 160 feet (270-degree azimuth) at gross weights between 43,000 and 45,000 pounds. Peak velocities for the CH-53E, at gross weights up to 56,000 pounds, exceed this threshold between 180 and 200 feet.

The Bell-Agusta 609 (which has a rotor diameter of 26 feet as compared to the XV-15 diameter of 25 feet) and the Sikorsky S-76 have thresholds of approximately the same distance. A comparison of the physical dimensions of both of these aircraft is provided in Figure 11. Threshold values for these two aircraft, as calculated using XV-15 (reference 3) and Sikorsky H-60 flight test date (reference 9) as references, are 95 feet (0/180 degree azimuths) and 80 feet (270 degree azimuth) for the 609 and 80 feet for the S-76. Gross weights for this comparison at a rotor height of 25 feet AGL are 16,000 pounds for the 609 and 11,700 pounds for the S-76.

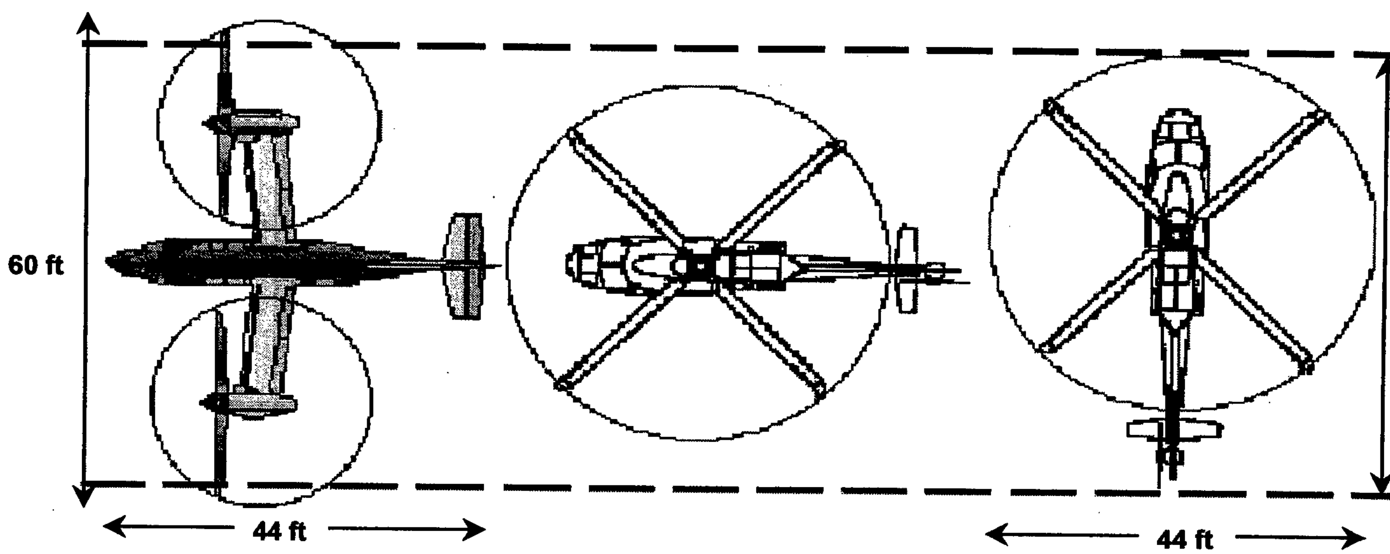


FIGURE 11 BELL-AGUSTA 609 / S-76C+ SIZE COMPARISON

If the above mentioned rotorcraft are considered to be ground taxiing the majority of the time, the rotorwash effect is dramatically reduced. The V-22 fixed position ground-taxi data in Figures 6 and 7 and the ground taxi maneuver data indicate that the 40 knot threshold is exceeded at DFACs of 80 to 100 feet. This range in separation distance is very close to a V-22 and the pilot will almost always have to maintain this separation distance to avoid other types of problems as well as minimize rotorwash effects. For XV-15, 609, and S-76 size aircraft, the rotorwash effects are minimal as ground crews and equipment are frequently found in very close proximity to the aircraft when taxiing. When ground taxiing these smaller aircraft, the noise level and the possibility of a main or tail rotor strike become as critical the issue of rotorwash effects.

The purpose of the comparisons presented in the previous paragraphs is to re-emphasize that similar size and gross weight class helicopters and tiltrotors have approximately the same rotorwash characteristics. While the details of the azimuth characteristics and the velocity profile shapes may differ in minor ways, the peak profile velocities are

approximately the same in the context of defining safe separation distances for similar classes of helicopters and tiltrotors. This statement is particularly true when one considers that safety margins must be added to account for winds, pilot technique, and other factors. It is also important to remember that pilots are sensitive to these separation distances for their own safety. From a vertiport design perspective, the use of the 40-knot threshold concept may not always be appropriate. For example, building structural components such as window frames may need to be designed for fatigue at a higher loading so that tiltrotors can taxi up to gates. In these situations, specific separation distances may need to be defined using more detailed procedures like those documented in reference 5, sections 4 through 6. However, this type of design effort must consider all types of similarly sized rotorcraft in defining safe separation distances, not just tiltrotors.

2.4.2 Rotorwash Forces on Personnel

Rotorwash generated overturning forces on personnel have been measured experimentally and studied in several research efforts. The U.S. Navy has documented data for this type of hazard in all of their rotorwash test reports (i.e. references 2, 3, and 8). However, the rotorwash velocities that are considered hazardous by Navy standards are based on unique military scenarios. Personnel involved in these scenarios have usually received training for working in rotorwash flow fields and have appropriate eye protection and clothing as needed. Overturning force criteria as developed by the Navy for military applications are presented in figure 12 (as obtained from reference 2). Reference 5 should be reviewed for a complete discussion of the background and criteria associated with this specific application.

If rotorwash generated overturning forces are investigated from a civilian perspective, then it quickly becomes obvious that the military criteria have limited application. References 5 and 7 provide estimates and rationale for the magnitudes of overturning force that are presently considered hazardous for civilian applications as based on available research. Table 4 summarizes these data (table from reference 5). It should be noted that these data are based on the U.S. Navy method that converts a velocity profile to an estimated overturning force (this procedure is documented in references 2 and 5).

Application of the criteria presented in Table 4 to actual vertiport design is beyond the scope of this report. These criteria are provided so that the V-22 and XV-15 test data can be evaluated using a meaningful design reference. The reader is referred to references 5 and 7 for discussion on the application of these criteria and associated requirements for vertiport structures such as personnel loading bridges. It should be noted that additional factors such as Federal laws for access to commercial aircraft by handicapped people, protection from the weather, and noise considerations will also have impacts on how personnel are handled in close proximity to CTR aircraft in a vertiport environment.

Flight test derived overturning forces as calculated using the Navy model for a human are summarized for the V-22 and XV-15 in figures 13 and 14 along the 0/180- and 270-degree azimuths. The hover velocity profile data were obtained directly from references 2 and 3 (figures 5 and 6 summarized the peak velocity values). These force data clearly indicate the advantages of taxi operations in a CTR environment. Forces generated in hover for a V-22 are well in excess of the 80 to 87 pound limit defined in Figure 12 up to the 75th weight percentile adult. In contrast, taxi forces for the V-22 at 91% rotor RPM even meet the Table 4 criteria presented for children (30 pounds or less) at distances greater than 70 feet from the center of the aircraft. At distances this close to a V-22, it is highly likely that the noise and engine exhaust would be unacceptable for civilian operations.

Practical comparisons of overturning force data can be presented in many ways for design applications. Two approaches will be presented in this report. The first approach is based on a graphical format originally presented in reference 3 to summarized XV-15 data applications involving trained personnel. The second approach is based on a graphical comparison using the proposed civilian CTR force criteria.

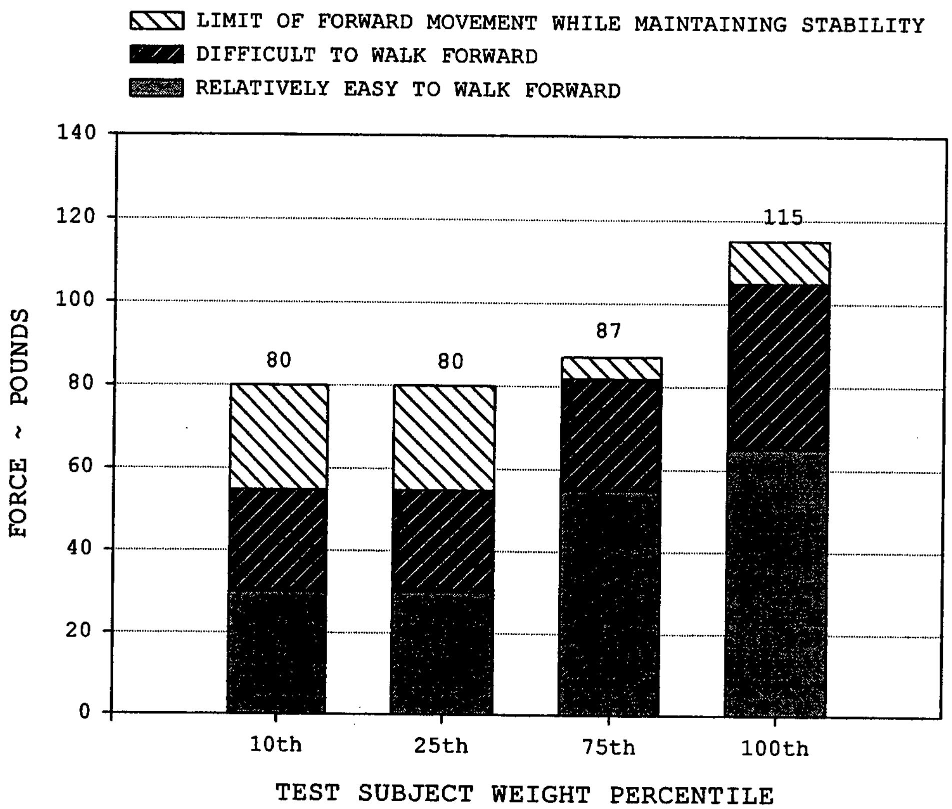


FIGURE 12 ABILITY OF TEST SUBJECTS TO WALK OR MOVE FORWARD UNDER VARIOUS AMOUNTS OF HORIZONTAL RESTRAINT LOADS APPLIED AT A POSITION 3 FT AGL (FROM REFERENCE 2)

TABLE 4 LIMITING VALUES OF OVERTURNING FORCE ON CIVILIAN PERSONNEL

Personnel Classification	Force Limit, lb
I: Trained and protected ramp personnel that work frequently in a rotorcraft downwash environment	80
II: Untrained and unprotected personnel that are rarely or never exposed to a rotorcraft downwash environment	40
III: Untrained and unprotected children that are walking without adult assistance in a rotorcraft downwash environment	30

The format used to document XV-15 hover overturning forces in figure 15 was first presented in reference 3. This format was intended to document results in a format useful for design purposes. The zones graphically outlined in the figure represent levels of effort required by trained personnel to accomplish work within a rotorwash environment. Definitions for these levels of effort are provided in the figure. Measured force values assigned to these definitions are also shown on the figure. The definition for Region I states that the region is between difficult and hazardous to walk through for personnel up to the 75th percentile. For the XV-15, this region is small and is located only directly in front of and aft of the aircraft.

The same format is approximated in figure 16 for the V-22 at a wheel height of 20 feet. The reason for the term "approximated" is that the non-linear relationships between region definitions and the values of assigned force in figure 15 do not lend themselves to graphics of the same shape and placement for design purposes. For instance, the force values on the boundaries of Region I in figure 16 are not a mirror image along the 0- and 180-degree azimuths if circles of constant radii are drawn. Also, the area of Region III for the XV-15 is still within the Region I boundaries for the V-22 at the same circle radii. An example of a more useable format for presentation of the V-22 data is therefore presented in figure 17. This figure highlights the non-linear nature of trying to define force boundaries. The drawback of this format is that it requires a very large sampling of flight test points to define the contours. Force contours of this type could be generated by computer analyses such as the ROTWASH program. However, research work would be required to develop a methodology to interpolate force values for azimuths between 0-, 90-, 180-, and 270-degrees since these are the only azimuths the ROTWASH model is now designed to calculate.

An alternative format for comparison of tiltrotor overturning forces is provided in figure 18. This figure compares the 0-, 180-, and 270-degree azimuth forces of the V-22 and XV-15 both in hover and (at a 20 to 25-feet wheel height) in a ground taxi configuration. The overturning force limits for civilian personnel are used as the breakpoints in the bar graphs as a function of the distance from aircraft center (DFAC). As a distance reference in the figure, the DFAC to the tip of the rotor is also graphed beside the ground taxi distance data.

In hovering flight, all three of the civilian force limits are exceeded for both the XV-15 and V-22 as based on the reference 2 and 3 flight test data. In contrast, overturning forces associated with ground taxi operations exhibit a much less severe restriction on personnel. The Class I limit is never exceeded for either the V-22 or the XV-15 and the Class II limit is exceeded only for the V-22 at 72 feet along the 0- and 180-degree azimuths. For the XV-15, the Class II limit is never exceeded along any azimuth. It must be noted that for consistency, the ground taxi data are scaled from the V-22 flight test data at 30 percent of hover OGE power along all three axes. This value results from the section 2.3 discussion where it was demonstrated that the worst case rotor power required value during taxi should be no greater than 30 percent. The data presented for the XV-15 are also based on the 30 percent value as calculated using the ROTWASH analysis.

In looking at the ground taxi data from a CTR operations perspective, one can conclude that ground taxi of tiltrotor aircraft does not present an overwhelming vertiport design problem. Rotorwash effects will need to be considered in any vertiport design and the method by which passengers are embarked will require serious consideration. However, there are additional safety/passenger comfort issues of the same magnitude of importance that must also be considered in vertiport design. These issues include:

1. the need to provide clearance between fixed and mobile objects and the tip of rotor blades under all combinations of lighting and weather conditions,
2. rotorwash effects from helicopter or other small tiltrotors that must or do air-taxi,
3. the noise and engine exhausts generated by helicopters and tiltrotors,
4. bad weather protection for embarking passengers, and
5. laws involving handicapped access to aircraft and transportation facilities.

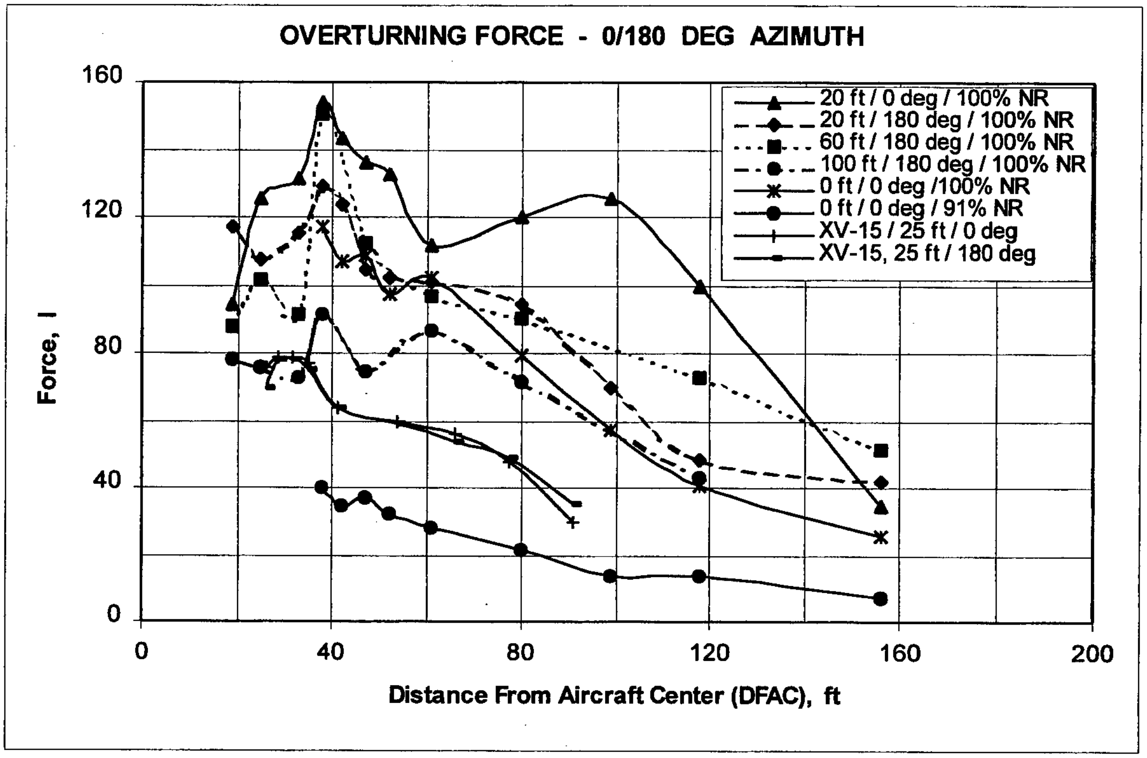


FIGURE 13 MEASURED OVERTURNING FORCE AS A FUNCTION OF DISTANCE ALONG THE INTERACTION PLANE (0/180-DEGREE AZIMUTH)

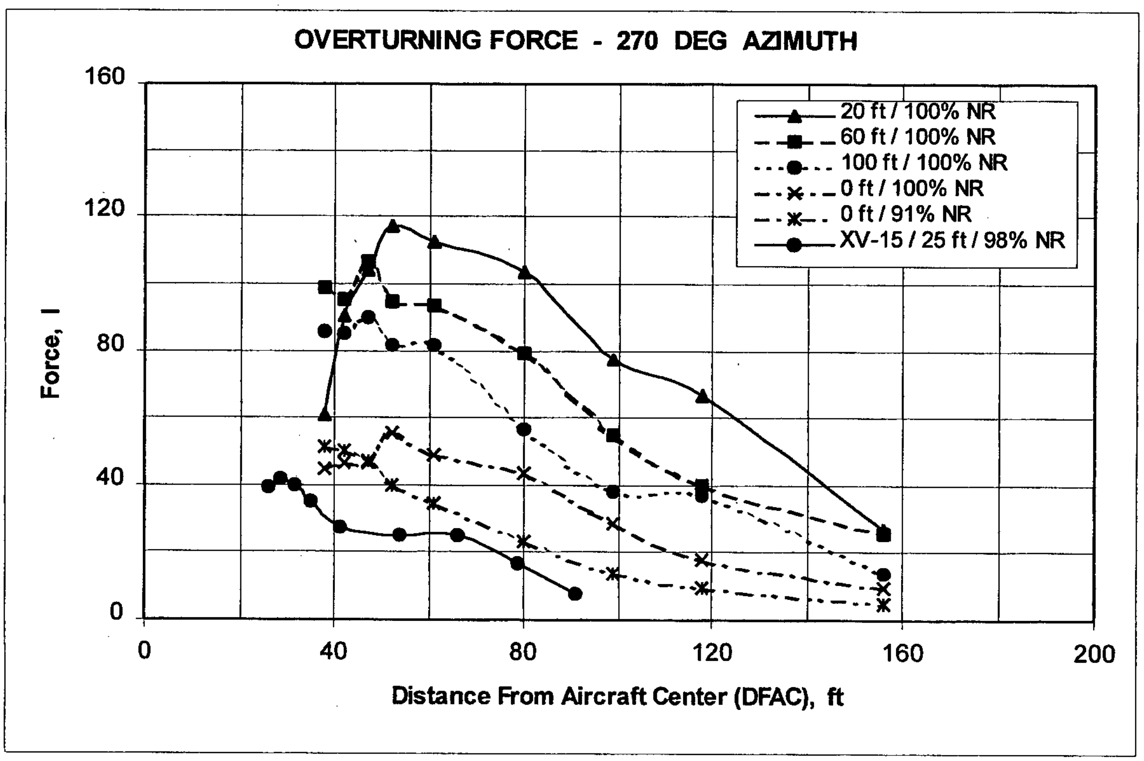
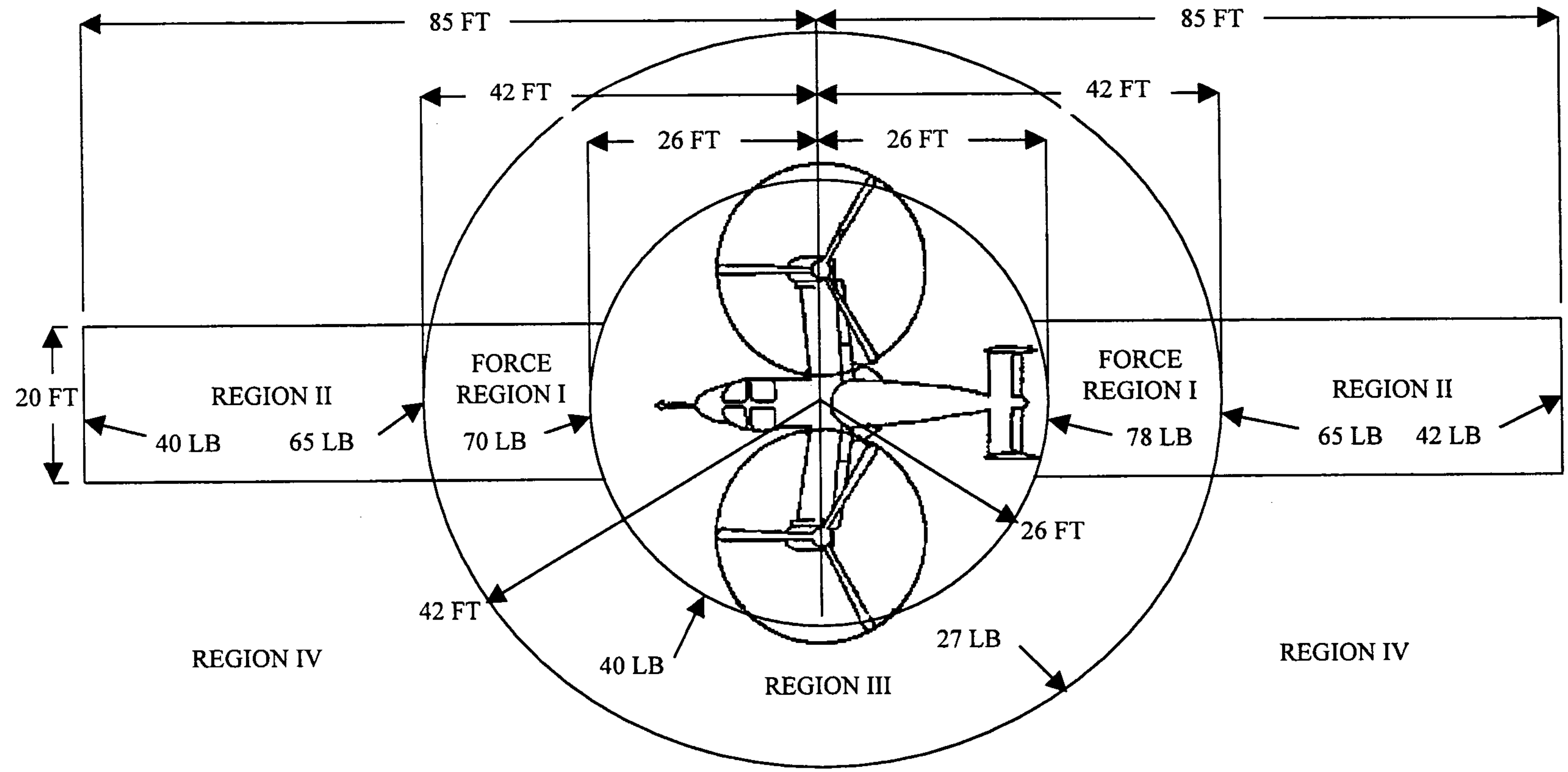


FIGURE 14 MEASURED OVERTURNING FORCE AS A FUNCTION OF DISTANCE FROM AIRCRAFT CENTER (270-DEGREE AZIMUTH)

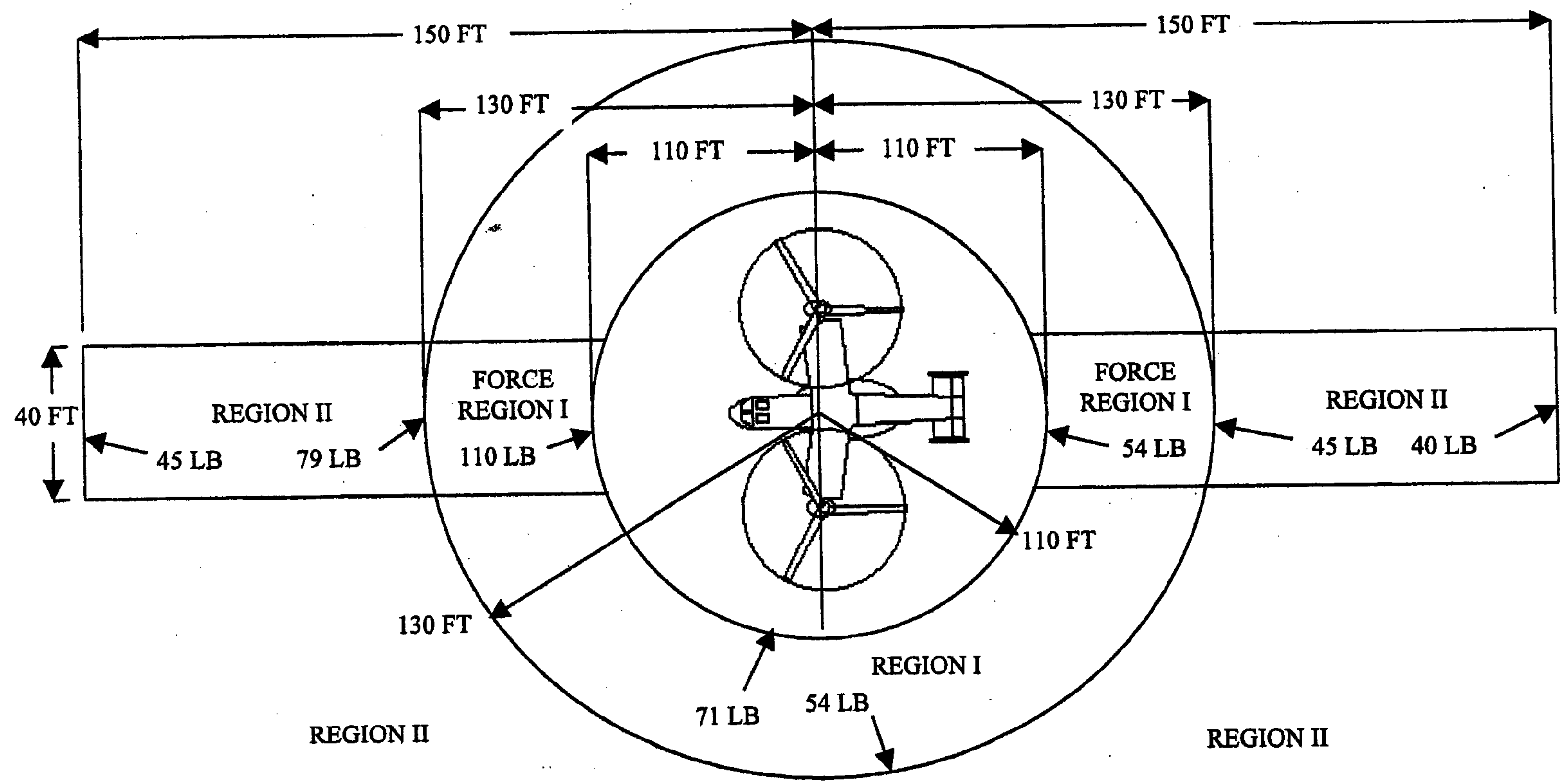


WHEEL HEIGHT = 25 FT

Data from U.S. Navy evaluation of XV-15 rotorwash characteristics, Report SY-14R-83, July 1983.

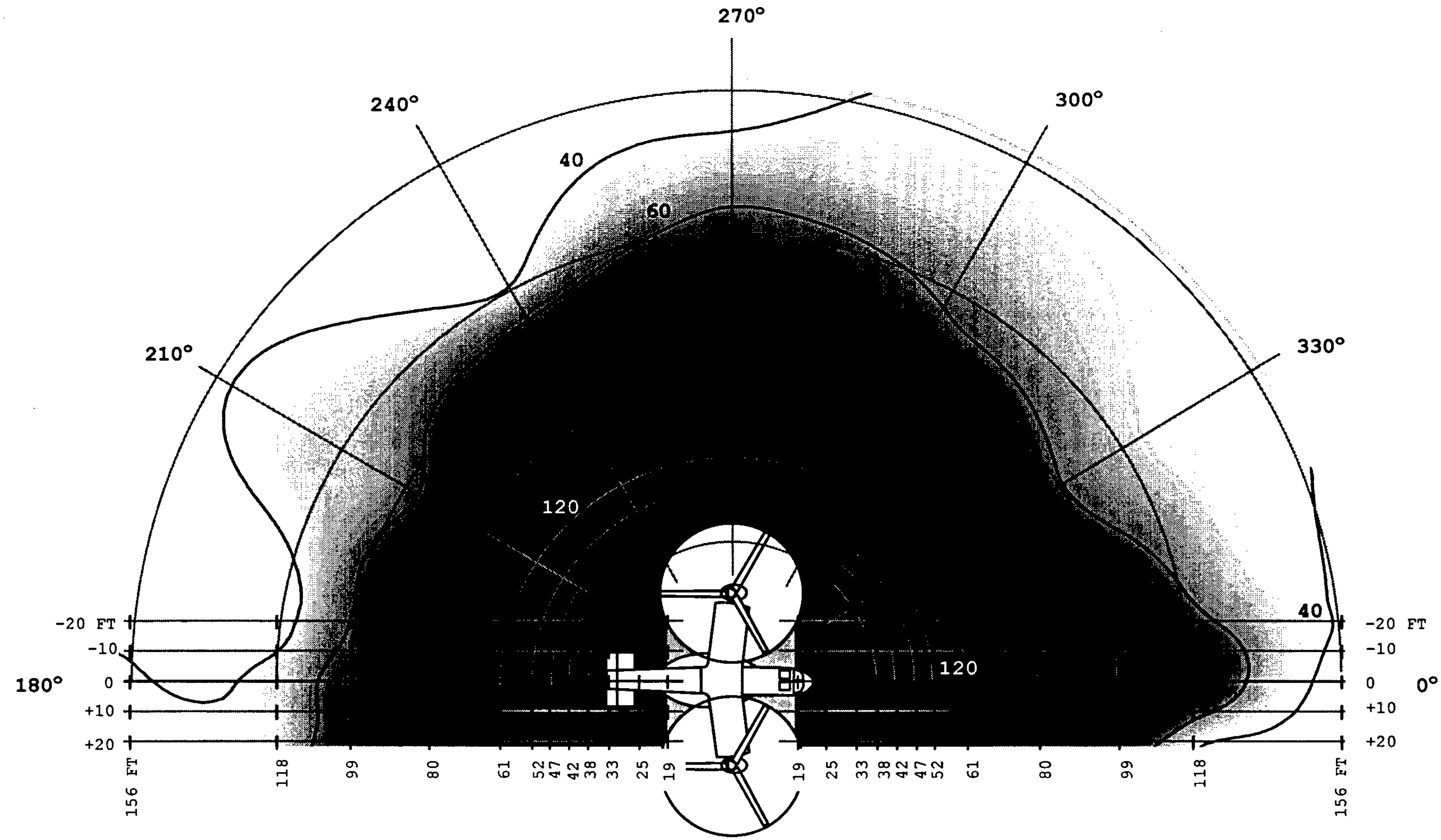
	Weight (Percentile), lb		
Regions	150 (25th)	171 (75th)	220 (99th)
I	Exceeds stability limit, hazardous	Difficult to walk through	Slightly difficult to walk through
II	Very difficult to walk through	Slightly difficult to walk through	No difficulty to walk through
III	Moderately difficult to walk through	No difficulty to walk through	No difficulty to walk through
IV	No difficulty to walk through	No difficulty to walk through	No difficulty to walk through

FIGURE 15 REGIONS OF OVERTURNING FORCE GENERATED BY THE XV-15 ON GROUND PERSONNEL



WHEEL HEIGHT = 20 FT

FIGURE 16 APPROXIMATE REGIONS OF OVERTURNING FORCE GENERATED BY THE V-22 ON GROUND PERSONNEL



FORCE CONTOUR IN POUNDS

Figure 17
V-22 PEAK DOWNWASH FORCES DURING A 20 FT AGL HOVER

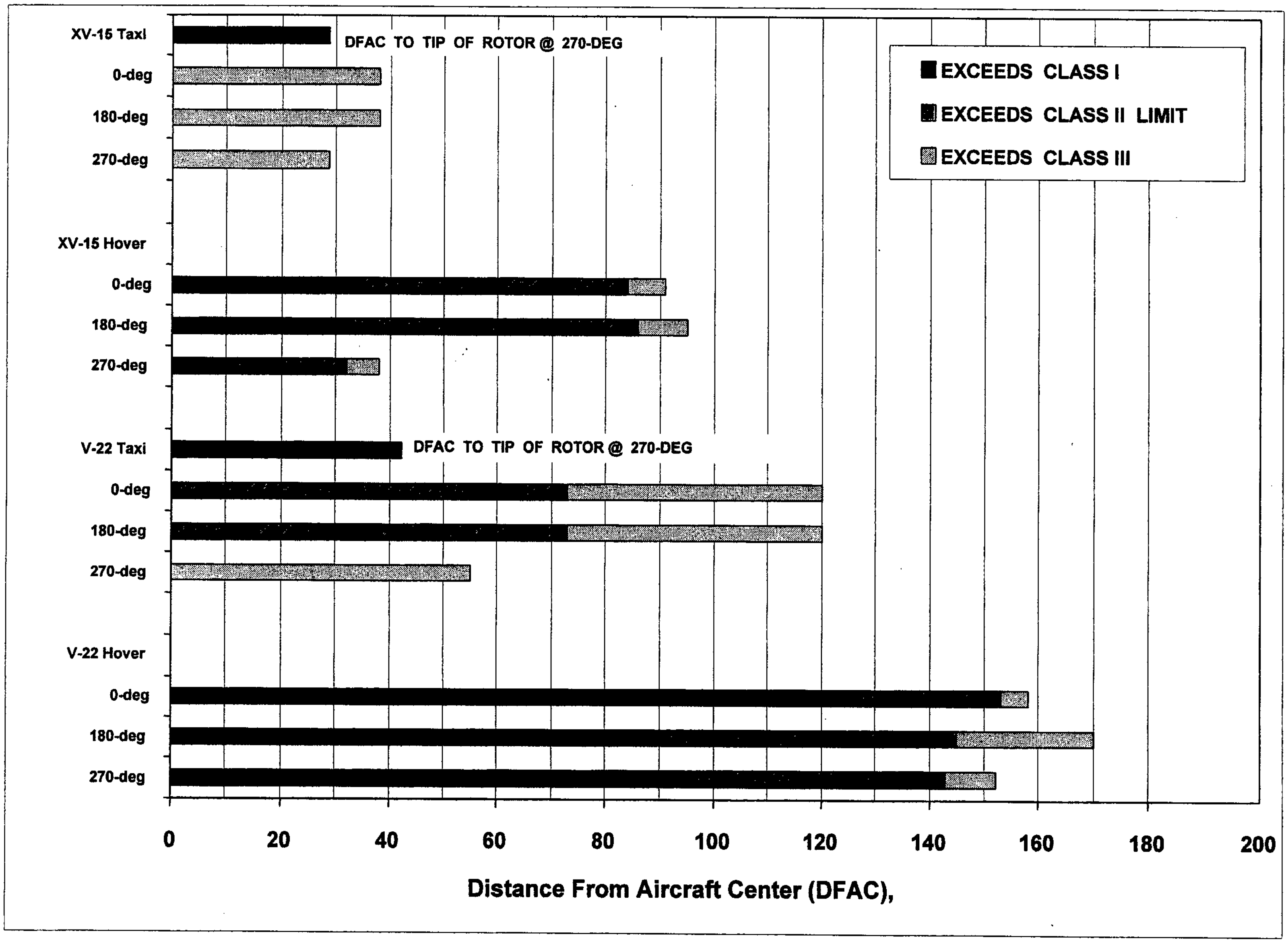


FIGURE 18 SEPARATION DISTANCE SUMMARY FOR CIVILIAN OVERTURNING FORCE LIMITS

3.0 CONCLUSIONS

Several conclusions can be made from the recently acquired V-22 flight test data and the analysis of these data. Conclusions that impact future rotorwash analysis efforts include:

1. Recently acquired Bell-Boeing V-22 rotorwash data are of excellent quality. When these data are utilized in conjunction with available XV-15 data, an excellent database exists from which vertiport design decisions can the made (reference 5 also documents helicopter rotorwash flight test data that support design efforts).

2. Rotorwash profile velocities and overturning forces measured during V-22 air taxi maneuvers for "normal" levels of pilot aggressiveness closely match the velocities and forces measured from a hovering V-22 at similar distances from the aircraft. Therefore, until additional flight test data are acquired that indicate otherwise, rotorwash effects during air taxi should be approximated using "corrected" hover rotorwash data. The data corrections should include tip path plane effects that account for the increased thrust that is required to accelerate and decelerate and the shifted location of rotorwash impingement with the ground plane. These corrections are documented in reference 5.

3. Ground taxi significantly reduces the effects of rotorwash because thrust levels are reduced. Analysis of flight test data indicates that the maximum rotor power required to ground taxi is no greater than 30 percent of the power required to hover out-of-ground effect. Therefore, the use of rotor thrust versus power required data, as corrected for rotor height above ground, can be applied to estimating CTR rotorwash velocities during ground taxi.

4. Research into defining a better metric for comparing the non-linear overturning force effects of various sizes of CTR aircraft in the context of the geometry of a vertiport layout is desirable.

Conclusions from the analysis of this report that impact vertiport design include:

5. Rotorwash velocities and overturning forces generated by large CTR aircraft (V-22 size class) have the potential to be extremely hazardous if the aircraft are allowed to air taxi. In contrast, ground taxi significantly reduces this hazard potential. Therefore, it is recommended that all vertiport design efforts emphasize ground taxi of large CTR aircraft from a small landing area to the parking area. Small CTR aircraft, such as the Bell XV-15 and Bell-Agusta 609, do not create a rotorwash hazard potential any greater than a similarly sized helicopter. In fact, some large skid helicopters may present a greater hazard in hover. Ground taxi of small CTR aircraft will further reduce rotorwash effects.

6. While ground taxi rotorwash generated forces on personnel are important, there are a number of additional safety/ passenger comfort factors of equal importance that must be considered in any vertiport design. These issues include:

   - the need to provide clearance between fixed and mobile objects and the tip of rotor blades under all combinations of lighting and weather conditions,

   - rotorwash effects from helicopter or other small tiltrotors that must or do air-taxi,

   - the noise and engine exhausts generated by helicopters and tiltrotors,

   - bad weather protection for embarking passengers, and

   - laws involving handicapped access to aircraft and transportation facilities.

REFERENCES

1. "Vertiport Design", Federal Aviation Administration, Washington D.C., Advisory Circular 150/5390-3, May 31, 1991.

2. Lake, R.E., and W.J. Clark, "V-22 Rotor Downwash Survey", Naval Air Warfare Center Aircraft Division, NAWCADPAX—98-88-RTR, July 9, 1998.

3. Harris, D.J., and R.D. Simpson, "Technical Evaluation of the Rotor Downwash Flow Field of the XV-15 Tilt Rotor Research Aircraft", Naval Air Test Center, Patuxent River, MD, Technical Report SY-14R-83, July 28, 1983.

4. Meyerhoff, C., and D. Gordge, "Navy Developmental Test (DT-IIA) of the V-22 Aircraft – Contributory Rotor Downwash Report", Naval Air Test Center, ACS-CR-90-04, SY71A, Summer 1990.

5. Ferguson, S.W., "Rotorwash Analysis Handbook, Volume I – Development and Analysis", Federal Aviation Administration, Washington D.C., DOT/FAA/RD-93/31,I, June 1994.

6. McVeigh, M.A., and K. Bartie, "V-22 Large-Scale Rotor Hover Performance and Wing Download Test", Bell-Boeing Report D901-99140-1, March 1985.

7. Smith, R.D., "CTR Rotorwash – Hazard Threshold For Civilian Passengers, Vertiport Design AC Revision – White Paper", Federal Aviation Administration, Washington D.C., AND-710, August 17, 1998.

8. Harris, D.J., and R.D. Simpson, "CH-53E Helicopter Downwash Evaluation", Naval Air Test Center, Patuxent River, MD, Technical Report SY-89R-78, August 1, 1978.

9. Meyerhoff, C., R.E. Lake, and LT D. Peters, "H-60 Helicopter Rotor Downwash Wind Velocity Evaluation", Naval Air Test Center Aircraft Division, Patuxent River, MD, Technical Report SY-3R-94, February 8, 1994.

APPENDIX A
BELL-BOEING V-22 ROTORWASH VELOCITY PROFILE DATA

U.S. Navy personnel at Patuxent River NAS acquired Bell-Boeing V-22 rotorwash data at four wheel heights above ground level (AGL) on December 18-19, 1997 and May 15, 1998. These heights are 0, 20, 60, and 100 feet AGL. All of the hover data acquired at 20, 60, and 100 feet AGL were acquired for Department Of Defense (DOD) purposes. Maneuvering rotorwash data, both in the air and on the ground, and fixed position data at several engine power levels with wheels on the ground were acquired to fulfill a Federal Aviation Administration (FAA) data request. The purpose of this appendix is to summarize the test data acquired for FAA research purposes. Reference A-1 should be reviewed for details on the hover test data and a description of the test equipment.

Rotorwash data acquired for the FAA included both static position and maneuvering test conditions. Test conditions for the static position data on the ground that were acquired at nine distances from the aircraft center (DFAC) are summarized in Table A-1. Maneuvering test conditions that were acquired both on the ground and in the air are defined in Table A-2. Graphs of the FAA test results, as listed in the tables, are provided for future research purposes.

TABLE A-1 V-22 STATIC TEST CONDITIONS

Figure Number	Azimuth, deg	Rotor RPM, %	Distance From Aircraft Center (DFAC), ft
1	0	100	38, 42, 47, 52, 61, 80, 99, 118, 156
2	0	91	38, 42, 47, 52, 61, 80, 99, 118, 156
3	270	100	38, 42, 47, 52, 61, 80, 99, 118, 156
4	270	91	38, 42, 47, 52, 61, 80, 99, 118, 156

Notes:

Azimuth 0 deg – directly in front of V-22 along the centerline
Azimuth 270 deg – directly out the V-22 left wing

TABLE A-2 V-22 MANEUVER TEST CONDITIONS

Figure Number	Azimuth, deg	Wheel Height, %	Type Of Maneuver
5	0	20	Deceleration at air taxi aggressiveness to a hover. Sensor located at a DFAC of approx. 61 ft while in hover (2R in front of the nose along centerline).
5	180	20	Acceleration at air taxi aggressiveness from a hover. Sensor located at a DFAC of approx. 61 ft (2R directly behind along centerline).
6	0	0	Deceleration from ground taxi to a parked position. Sensor located at a DFAC of approx. 61 ft while parked (2R in front of the nose along centerline).
6	0	0	Acceleration backwards from parked position. Sensor located at a DFAC of approx. 61 ft while parked (2R in front of the nose along centerline).
7	270	0	Constant speed taxi turn of 180 degrees. Sensor located at a DFAC of approx. 61 ft at the 90 degree point in the turn (along the line running outward from the aircraft center through the center of the left rotor hub, azimuth of 270 degrees).

REFERENCE

A-1. Lake, R.E., and W.J. Clark, "V-22 Rotor Downwash Survey", Naval Air Warfare Center Aircraft Division, NAWCADPAX—98-88-RTR, July 9, 1998.

Notes:

V-22 A/C 8, Test 192, Records 127-135
Wind < 3 kts

Wheel Height = 0.0 ft	Average Rotor Power = 2002.0 SHP
Rotor Height = 21.3 ft	Average Rotor Speed = 397.0 RPM (100%)
Rotor Radius = 19.0 ft	Density Ratio = 1.005

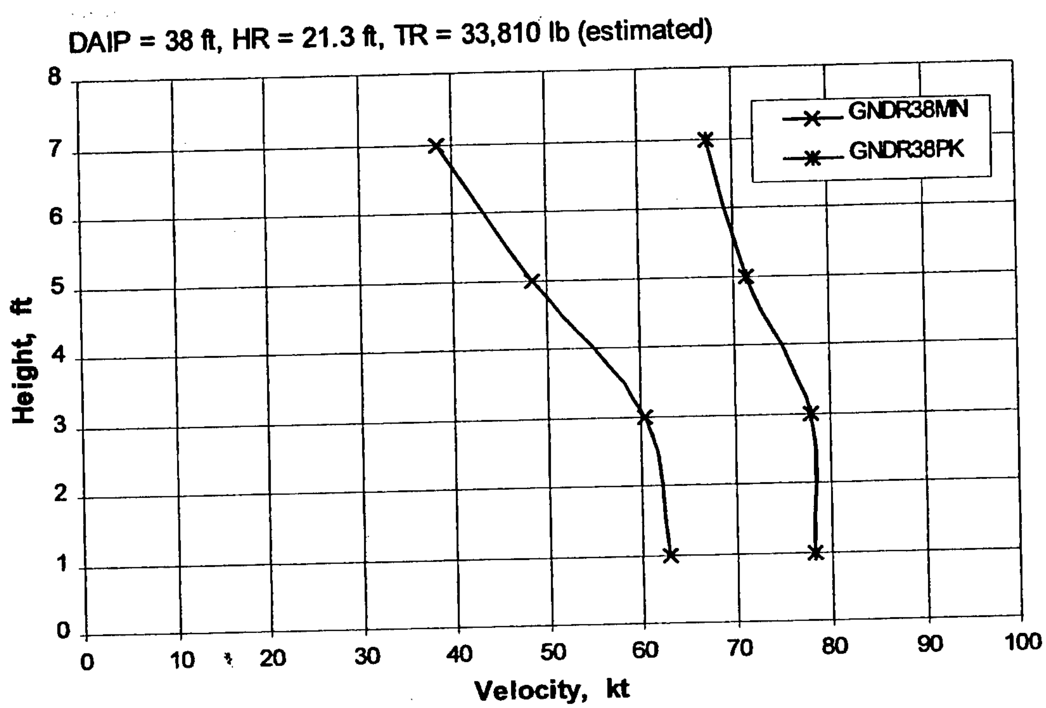
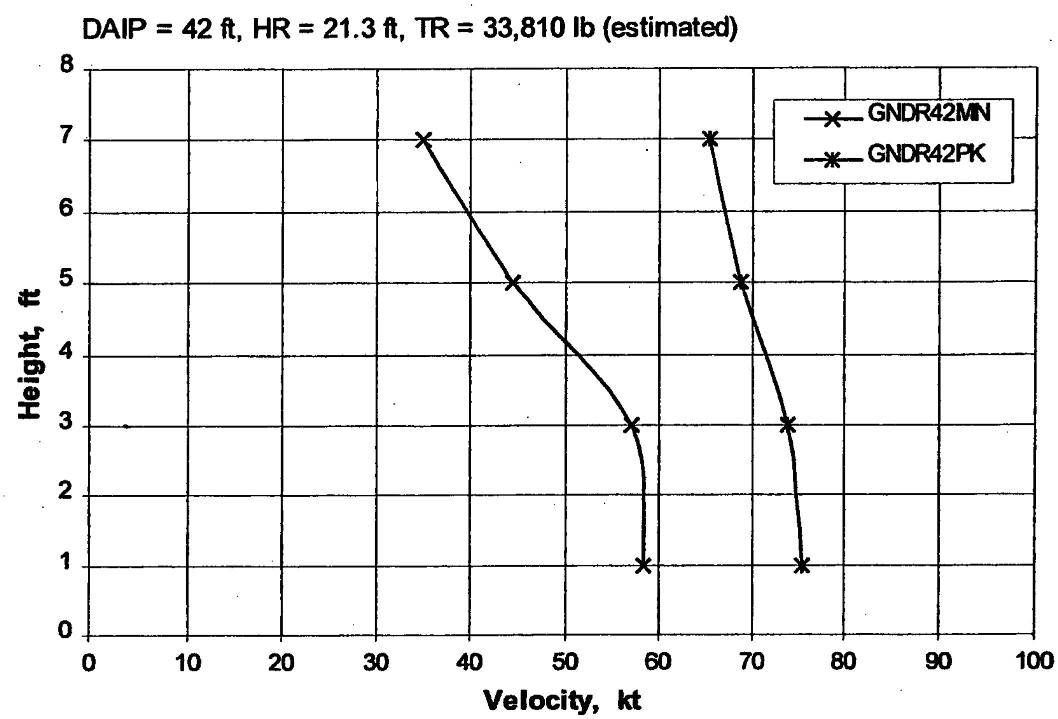


FIGURE A-1 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100%



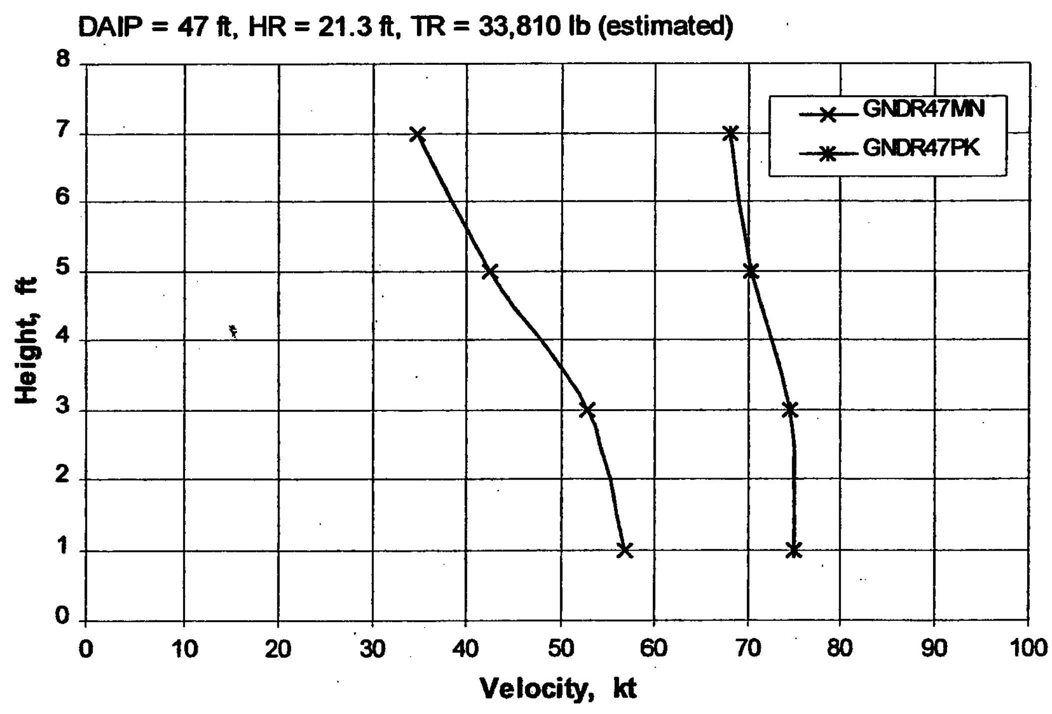
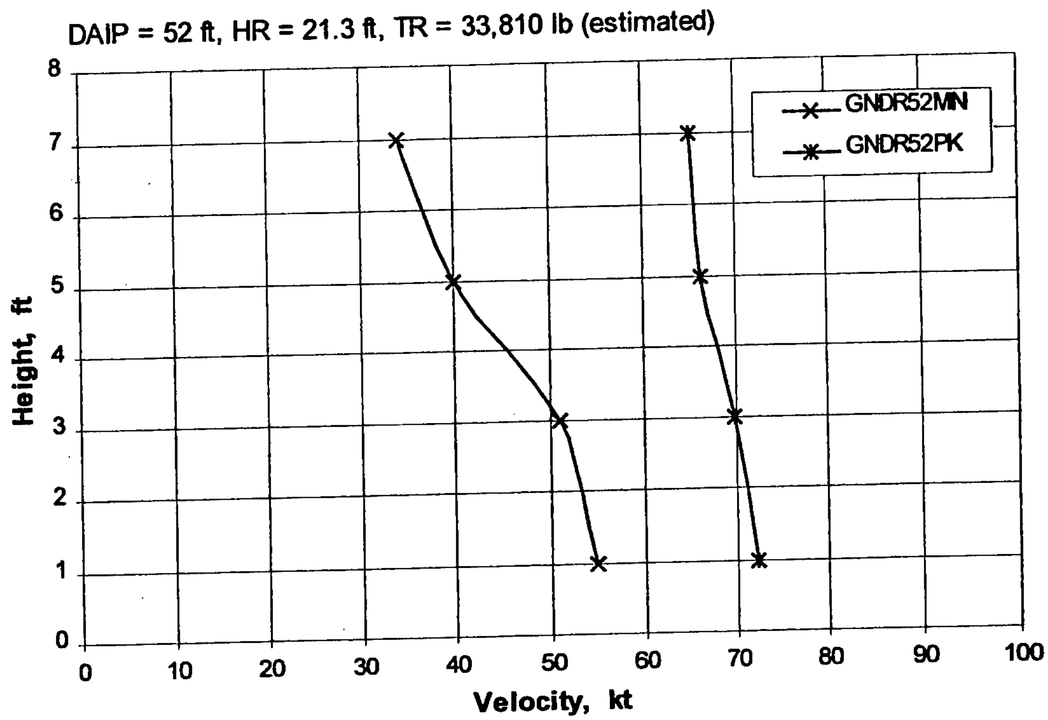


FIGURE A-1 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)



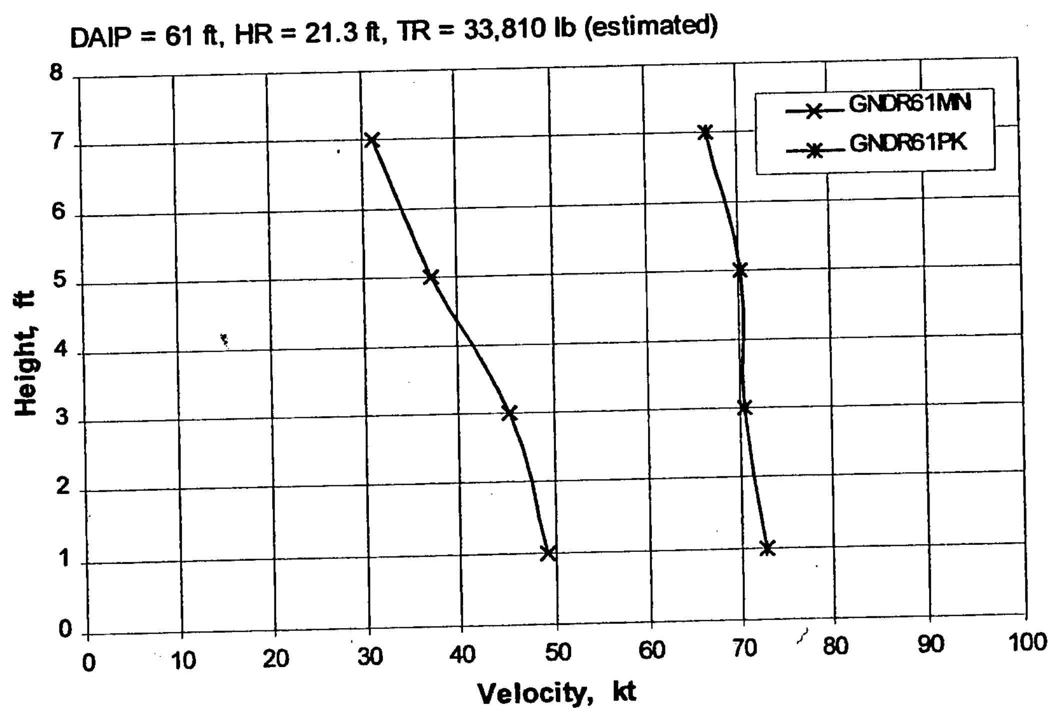
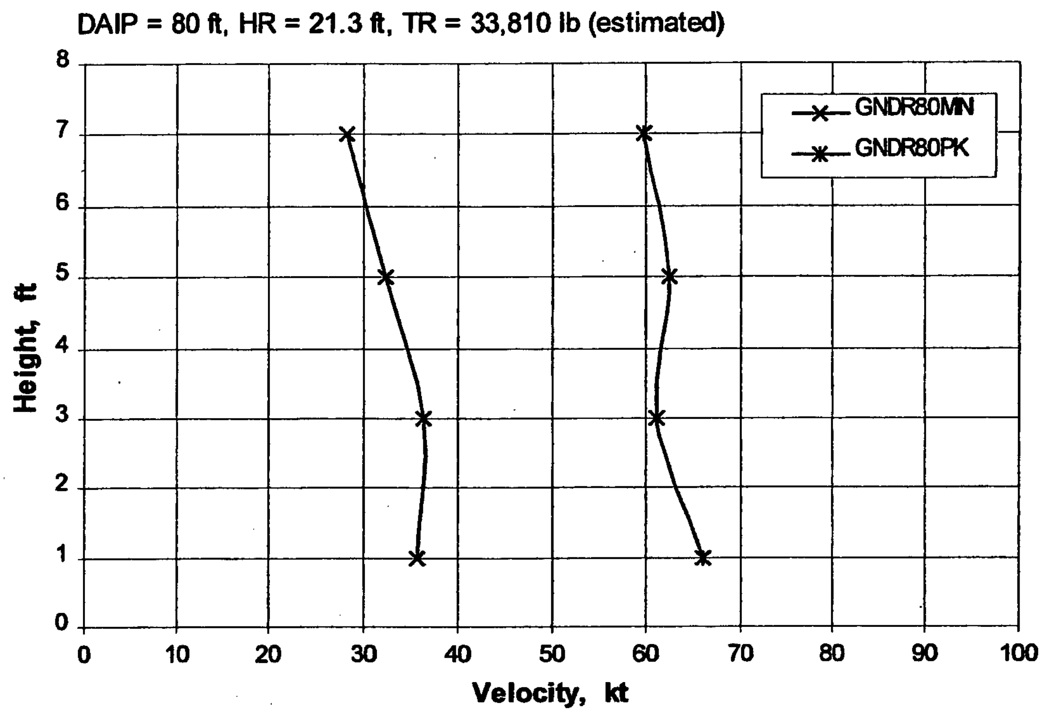


FIGURE A-1 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)



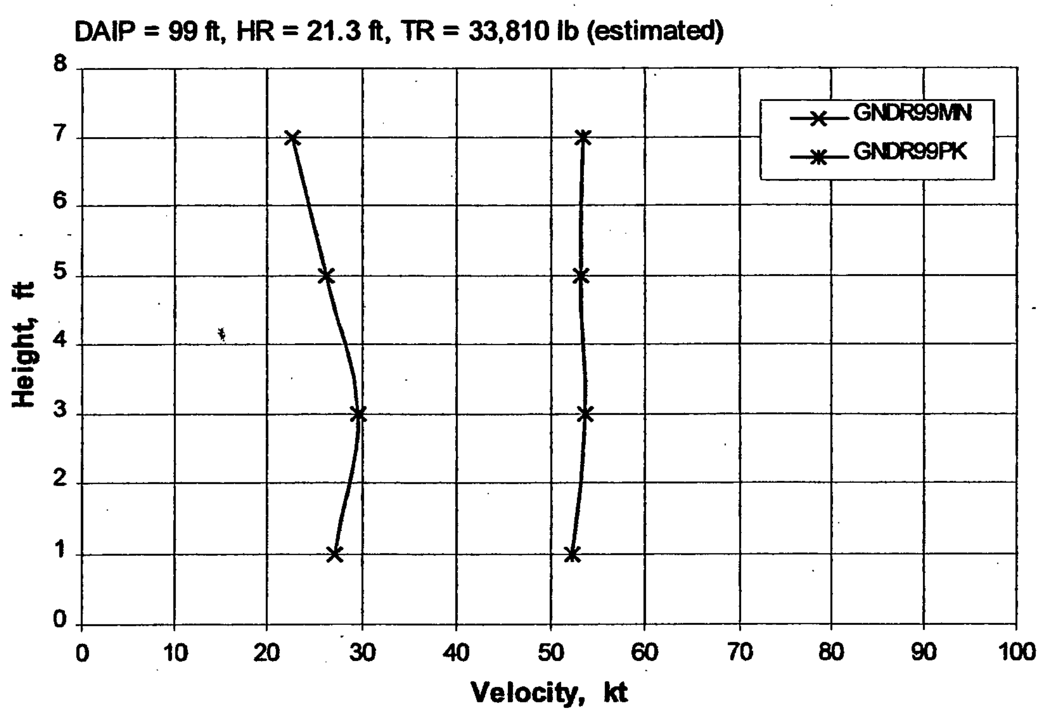
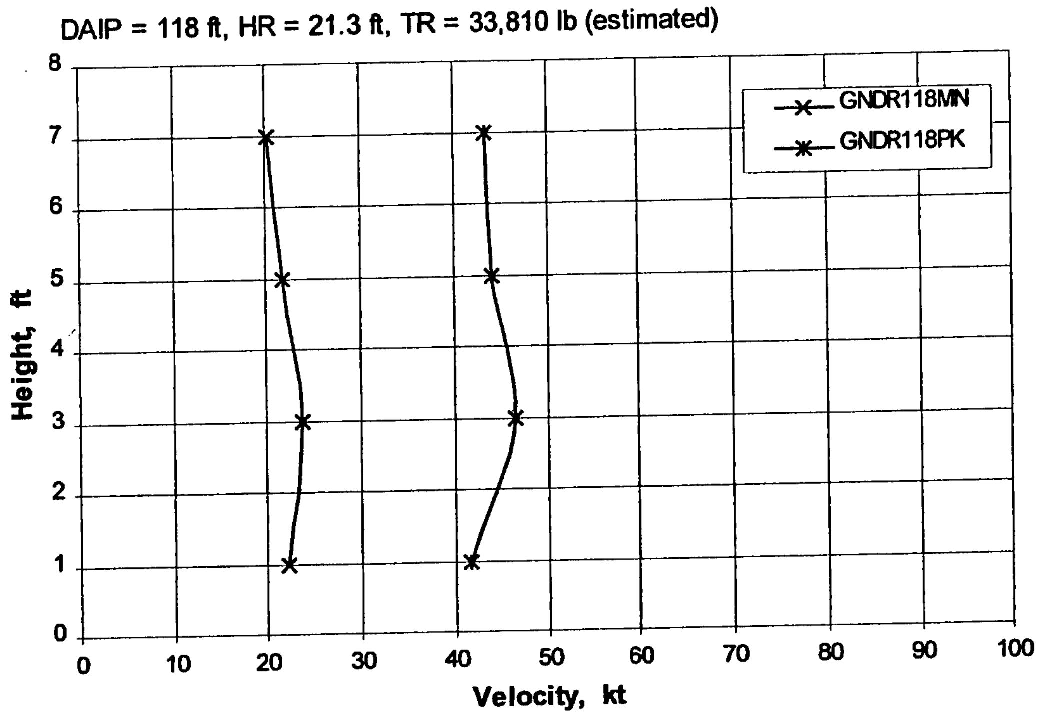


FIGURE A-1 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)



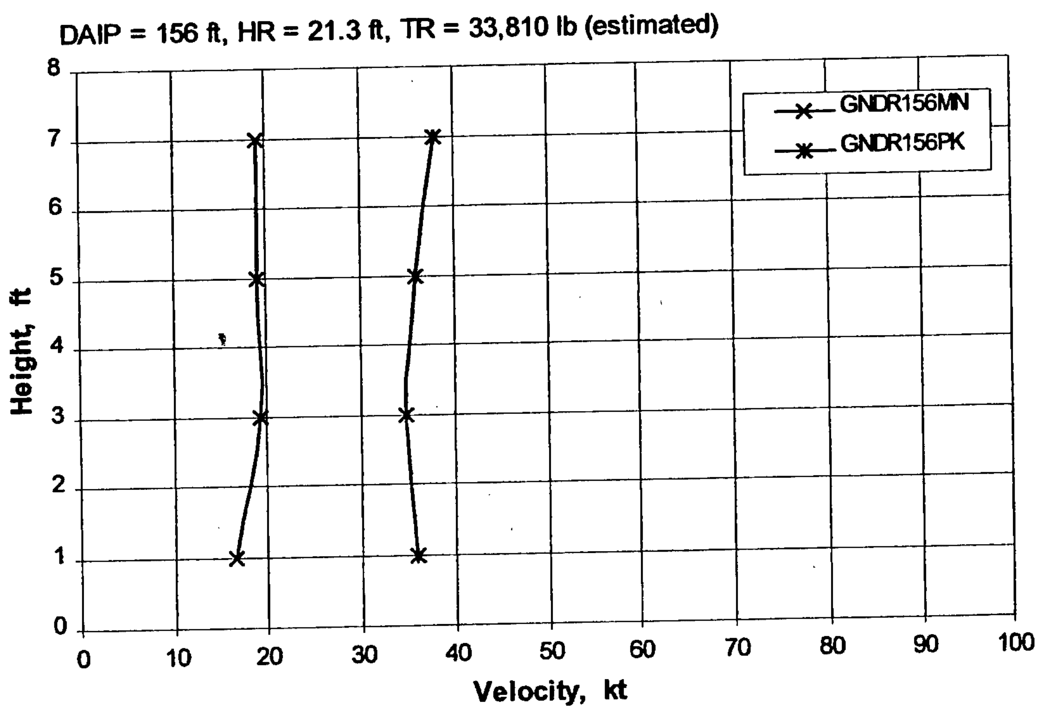


FIGURE A-1 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)

Notes:

V-22 A/C 8, Test 192, Records 137-144
Wind < 3 kts

Wheel Height = 0.0 ft
Rotor Height = 21.3 ft
Rotor Radius = 19.0 ft

Average Rotor Power = 603.0 SHP
Average Rotor Speed = 364.0 RPM (91%)
Density Ratio = 1.005

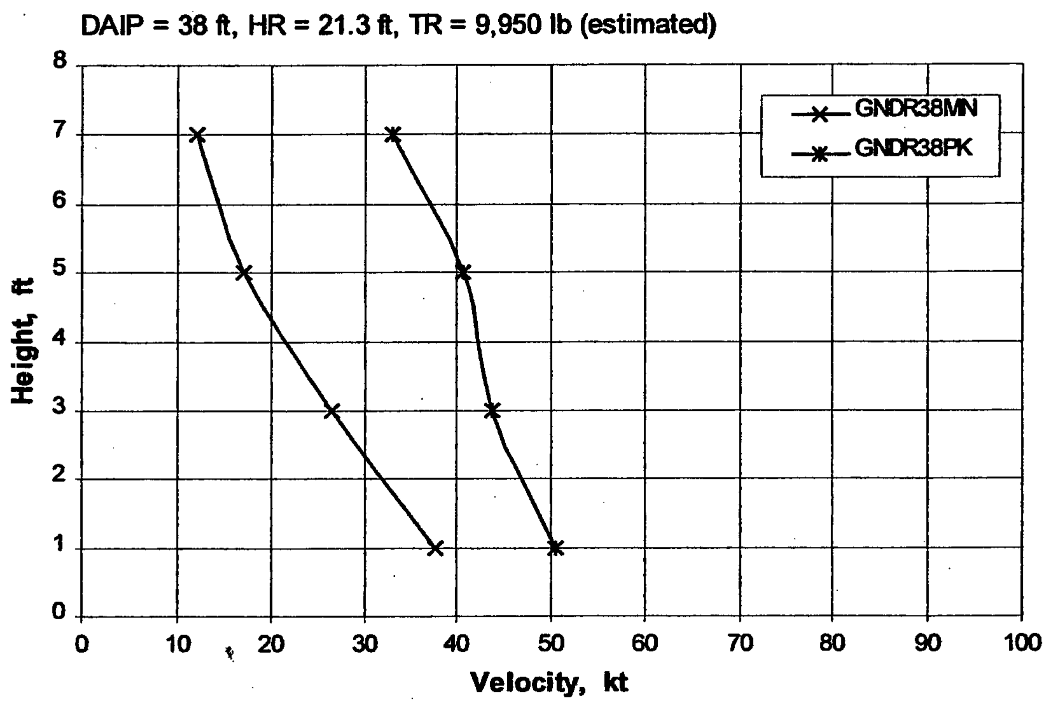
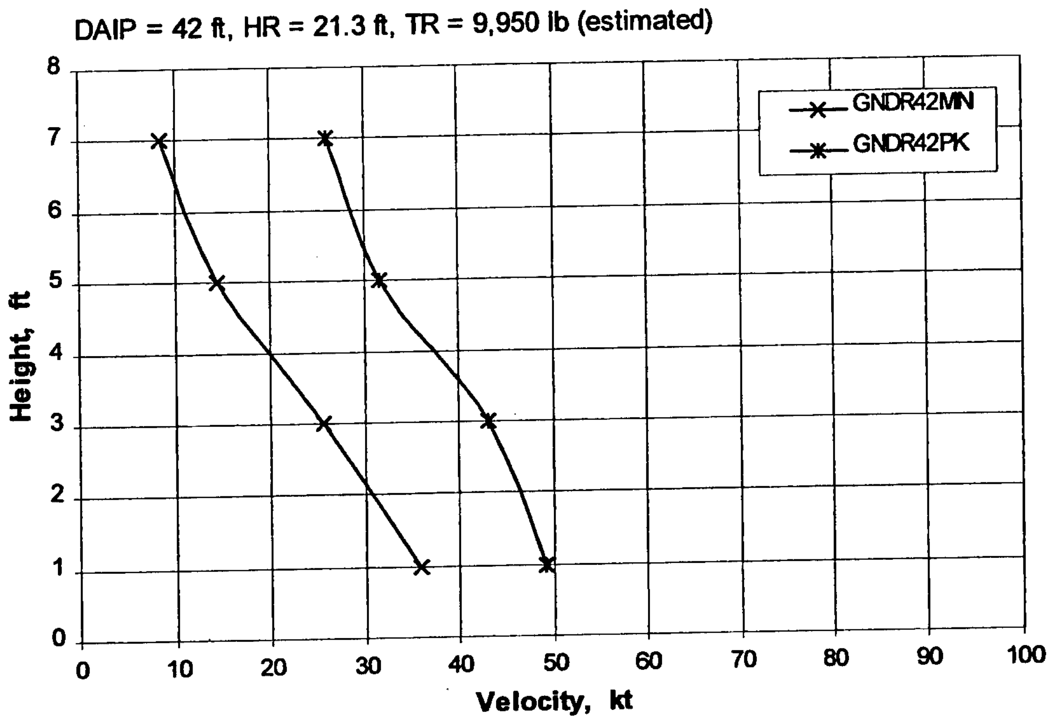


FIGURE A-2 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91%



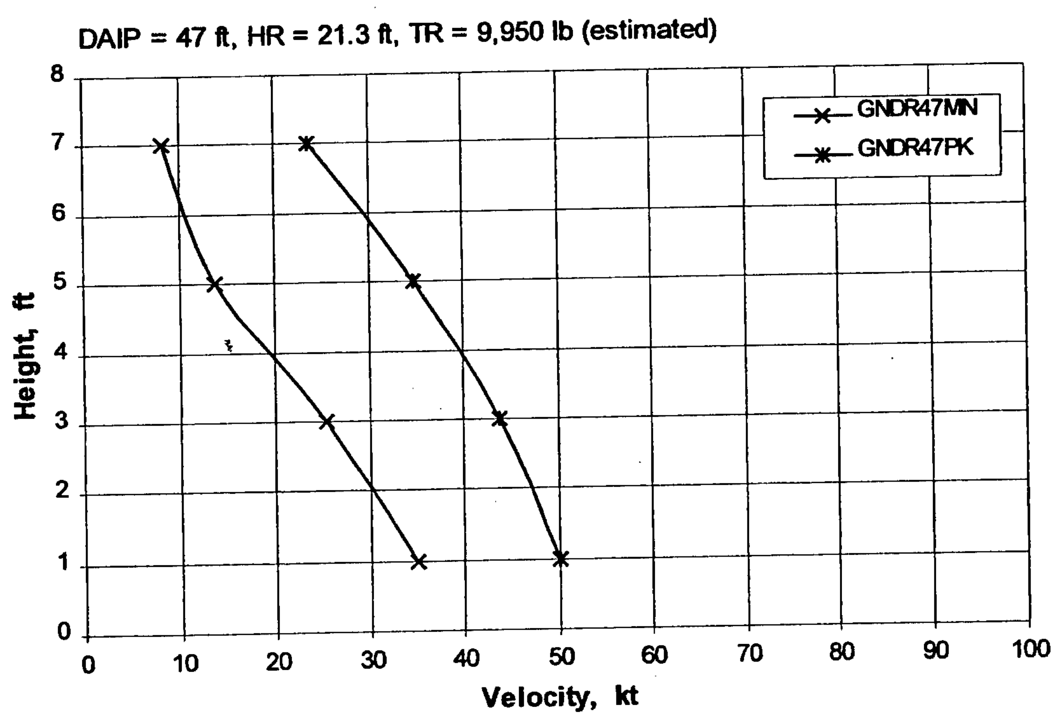
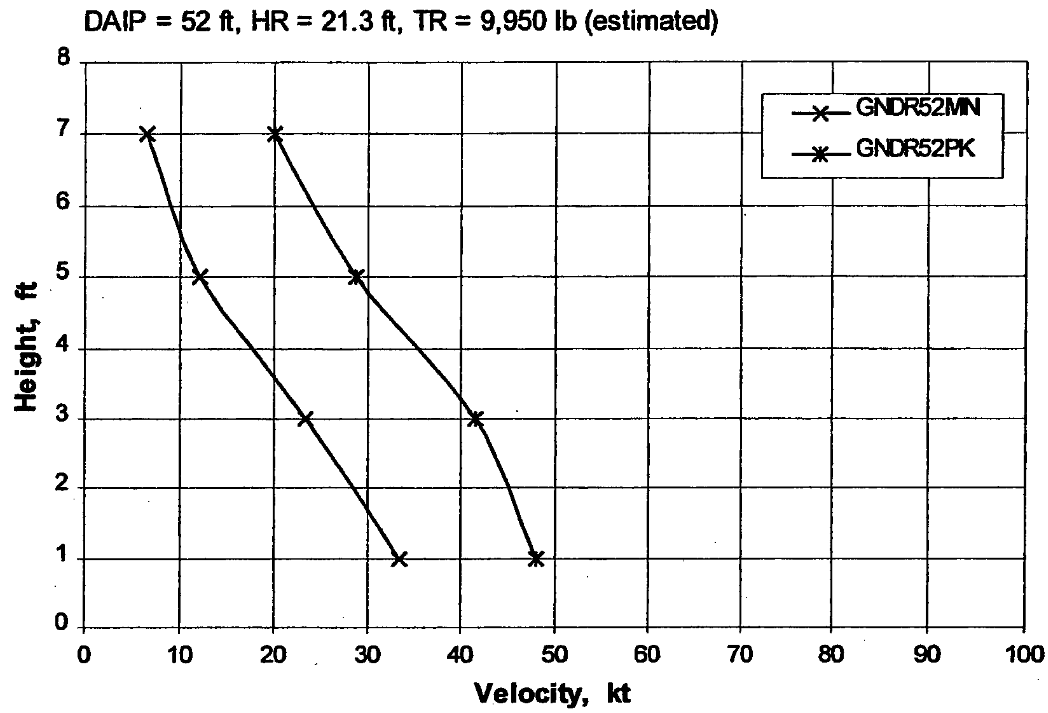


FIGURE A-2 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)



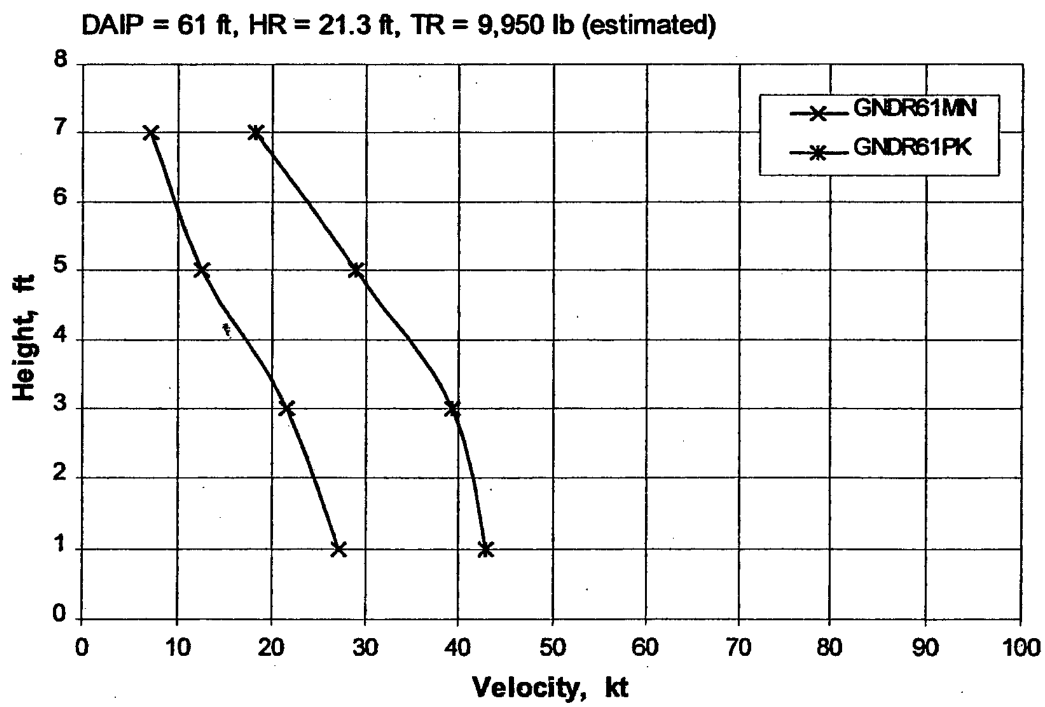
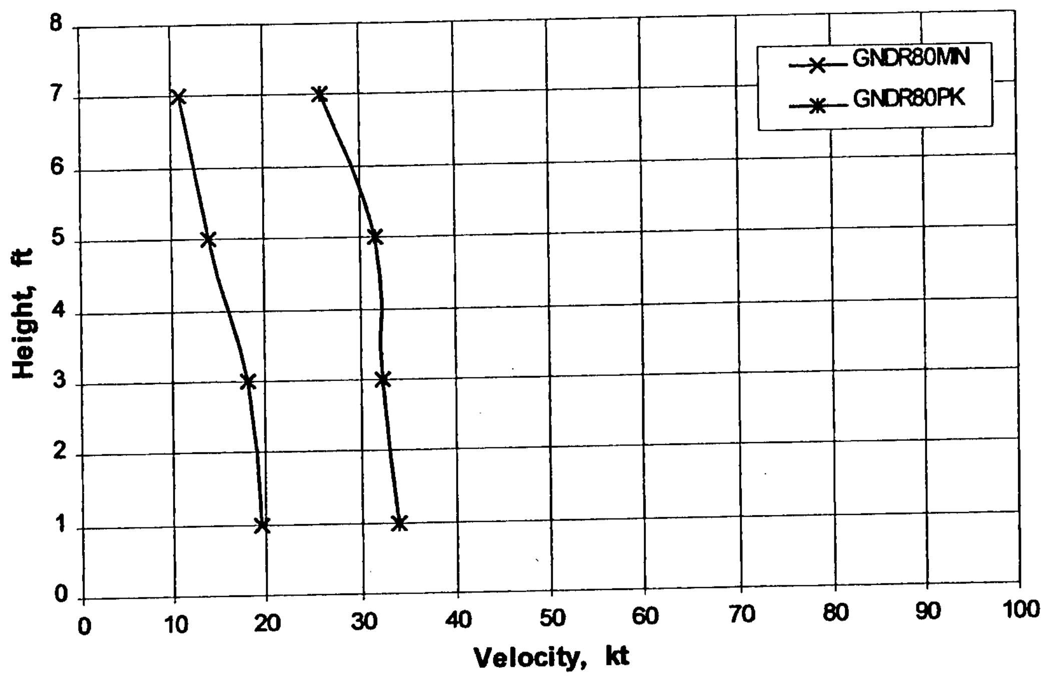


FIGURE A-2 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)

DAIP = 80 ft, HR = 21.3 ft, TR = 9,950 lb (estimated)



DAIP = 99 ft, HR = 21.3 ft, TR = 9,950 lb (estimated)

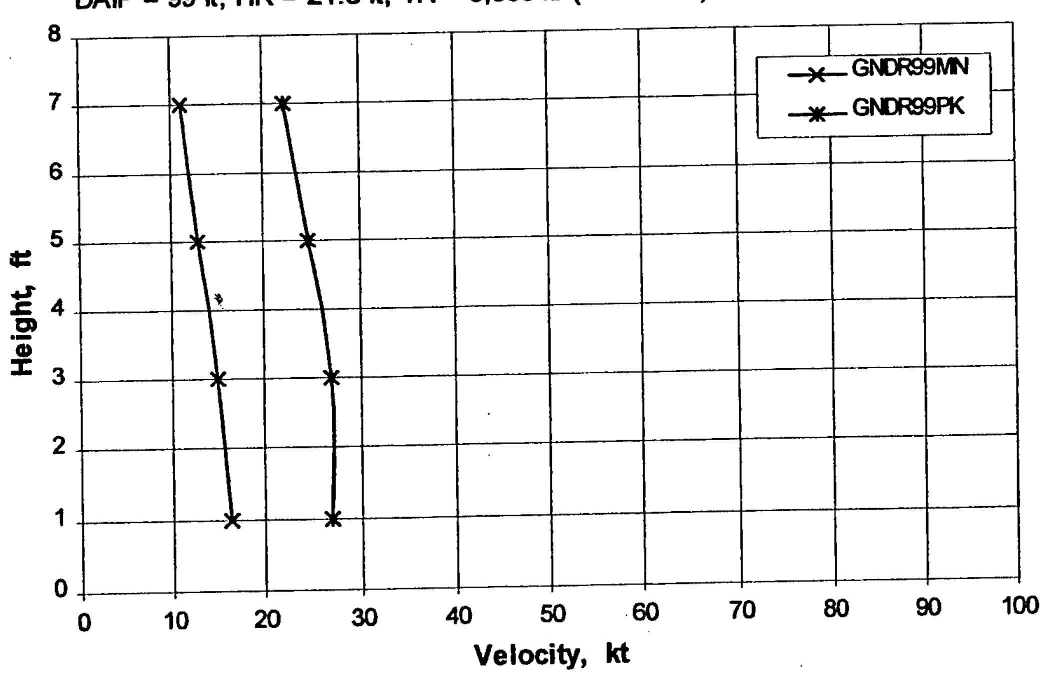
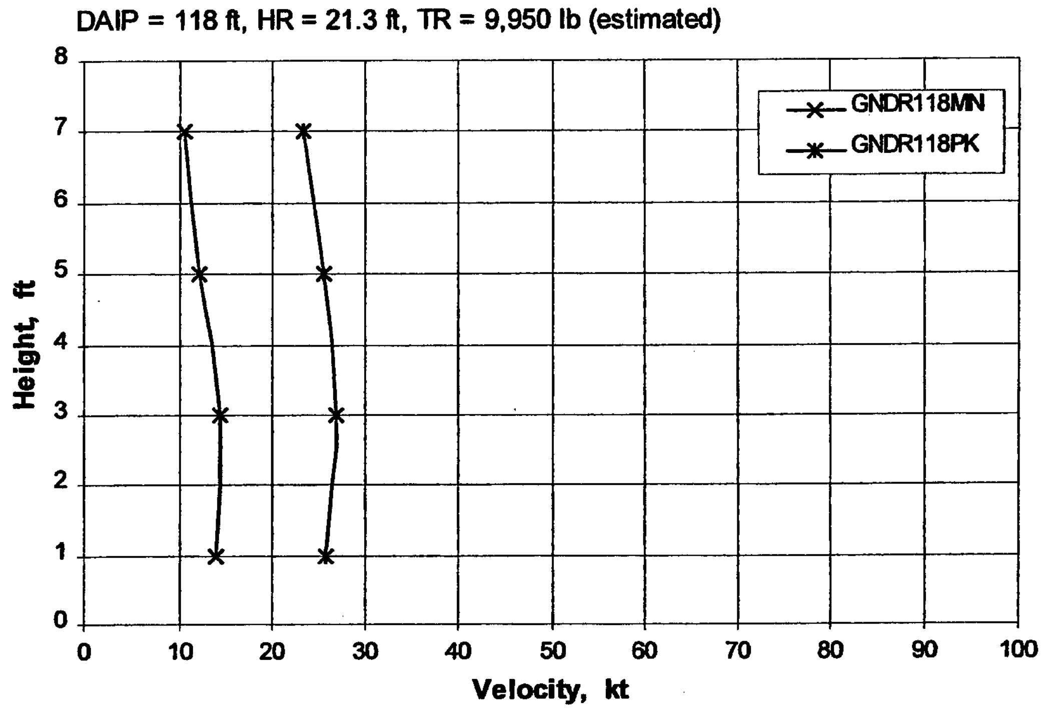


FIGURE A-2 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)



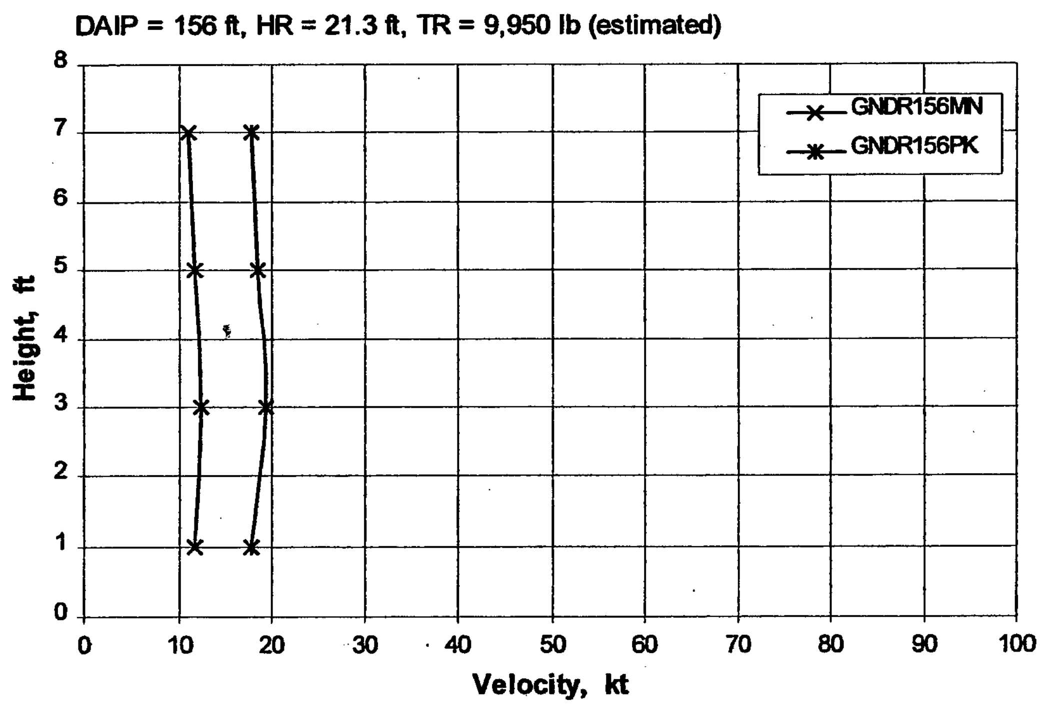


FIGURE A-2 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 0 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)

Notes:

V-22 A/C 8, Test 192, Records 147-155
Wind < 3 kts

Wheel Height = 0.0 ft	Average Rotor Power = 1219.0 SHP
Rotor Height = 21.3 ft	Average Rotor Speed = 397.0 RPM (100%)
Rotor Radius = 19.0 ft	Density Ratio = 1.005

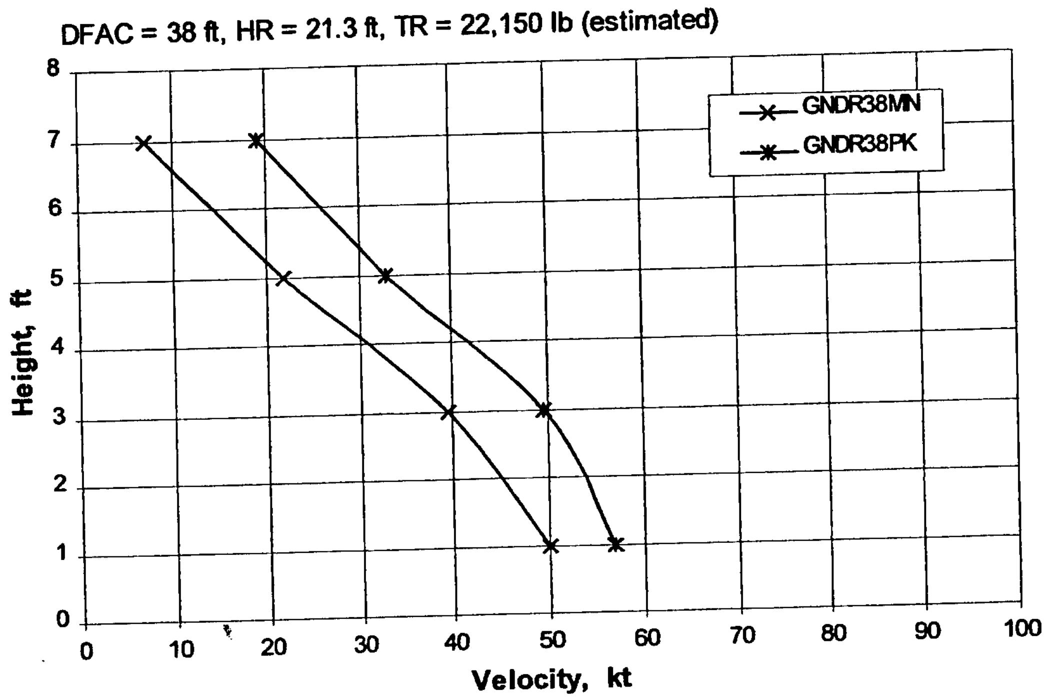
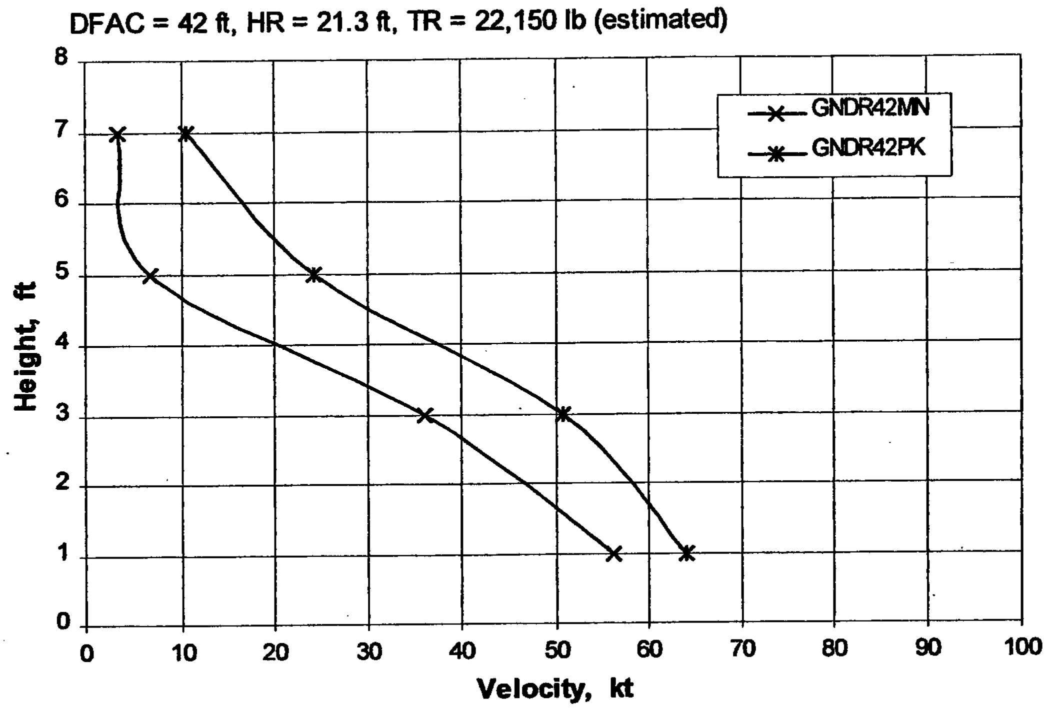


FIGURE A-3 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100%



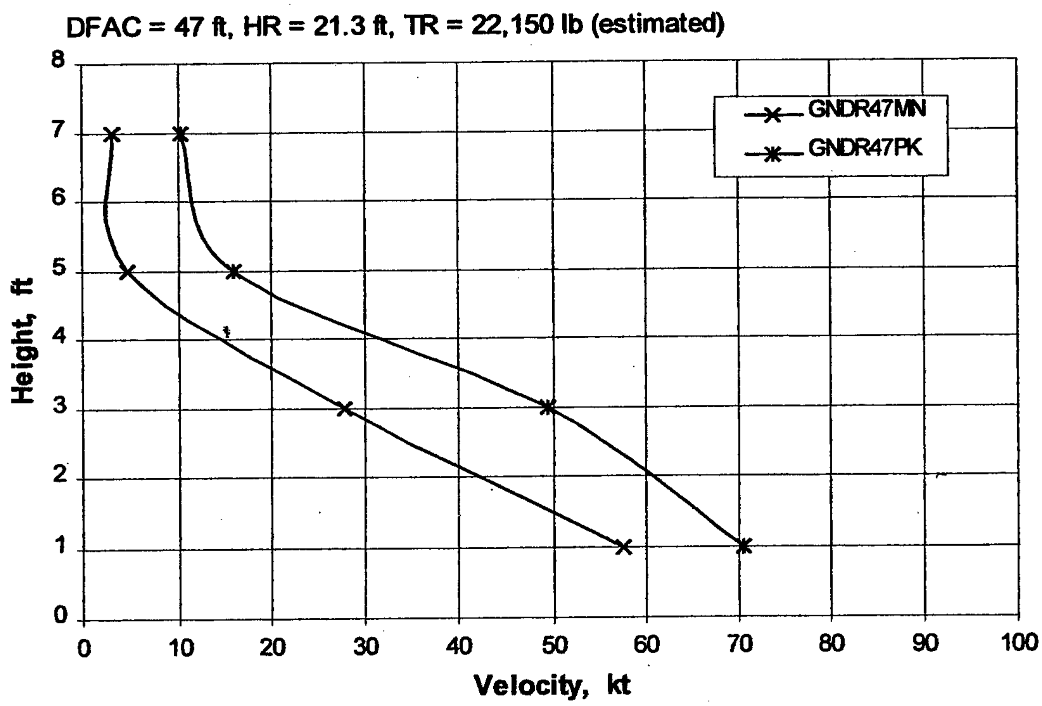
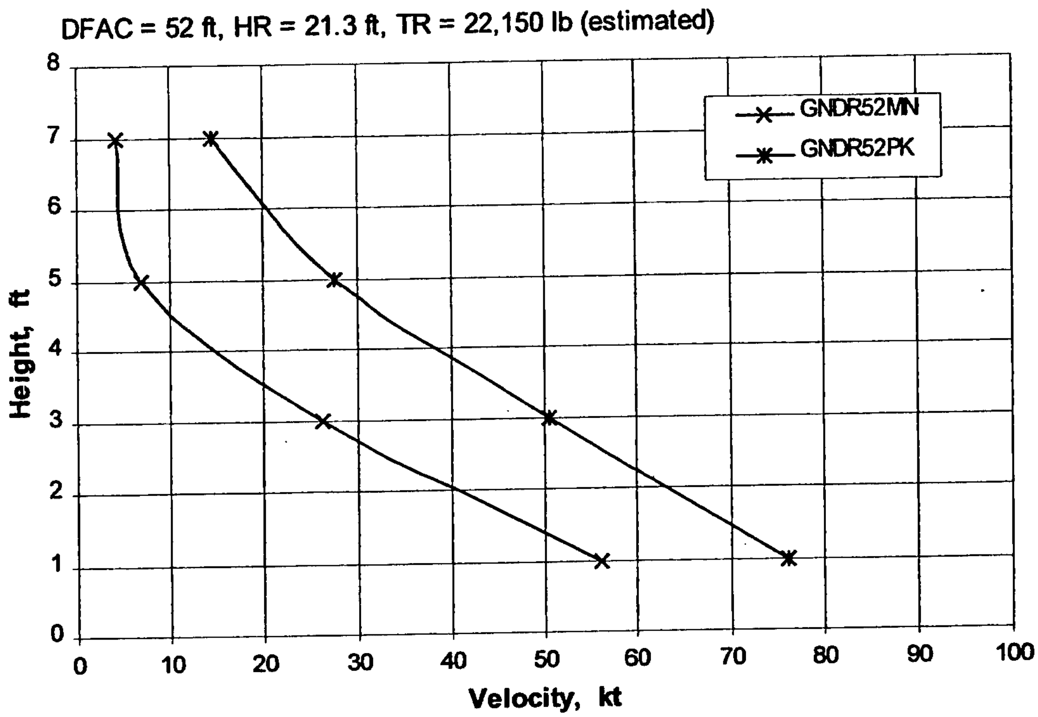


FIGURE A-3 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)



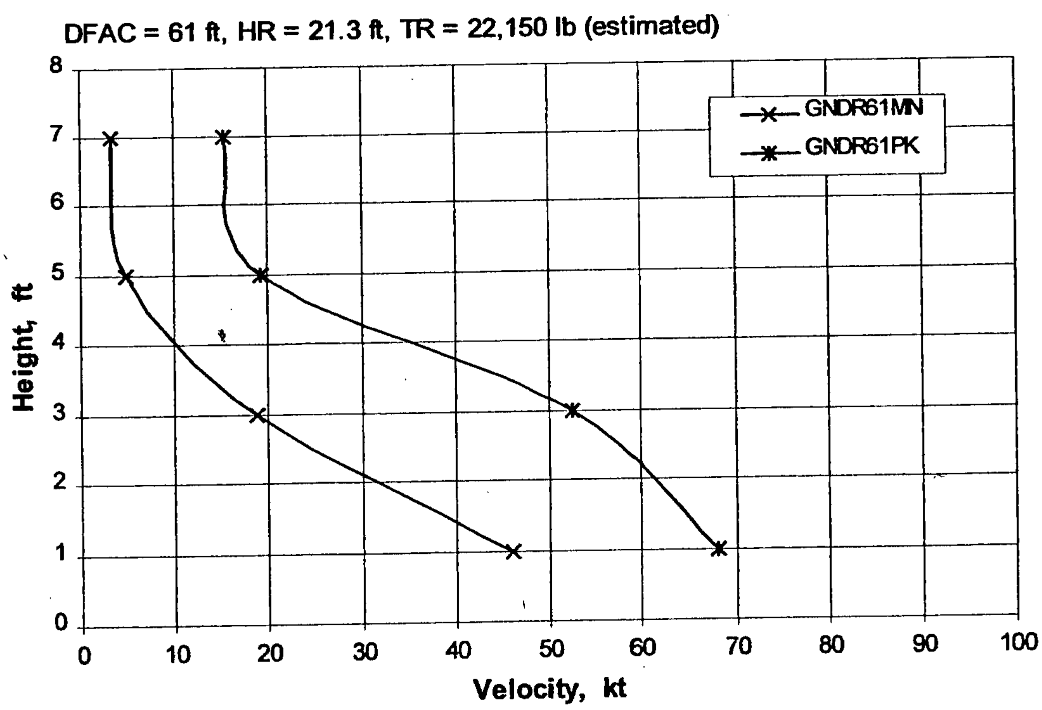
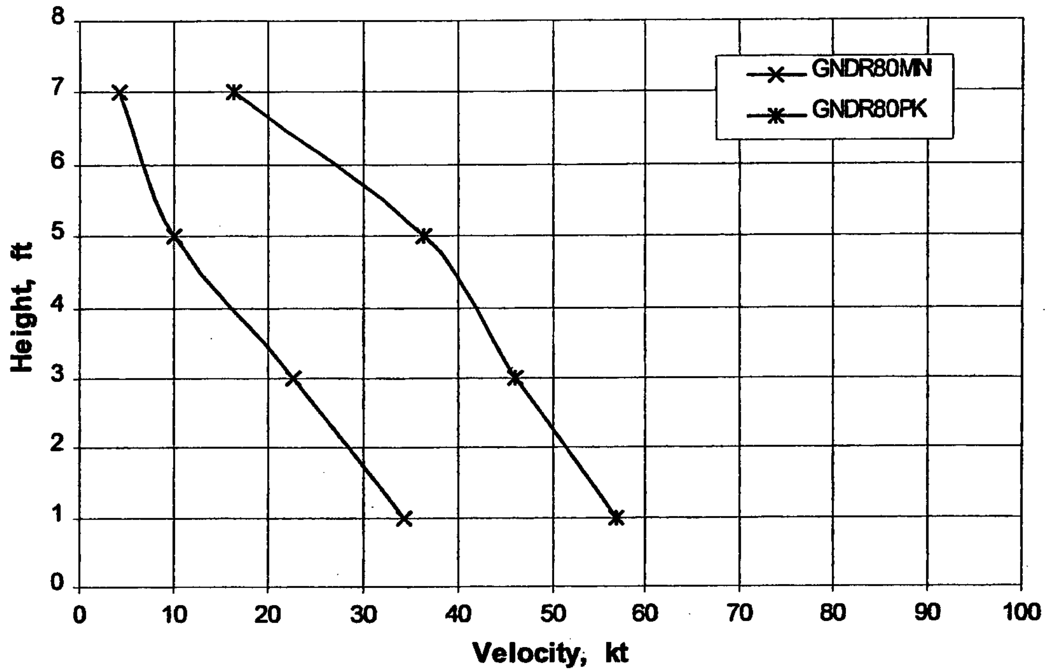


FIGURE A-3 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)

DFAC = 80 ft, HR = 21.3 ft, TR = 22,150 lb (estimated)



DFAC = 99 ft, HR = 21.3 ft, TR = 22,150 lb (estimated)

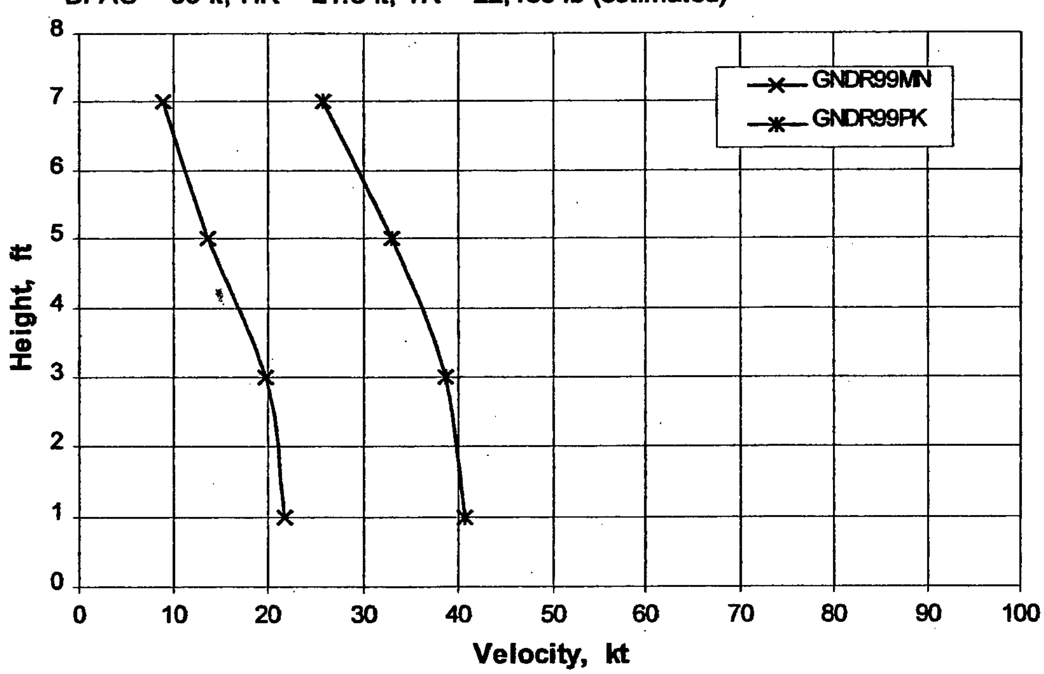
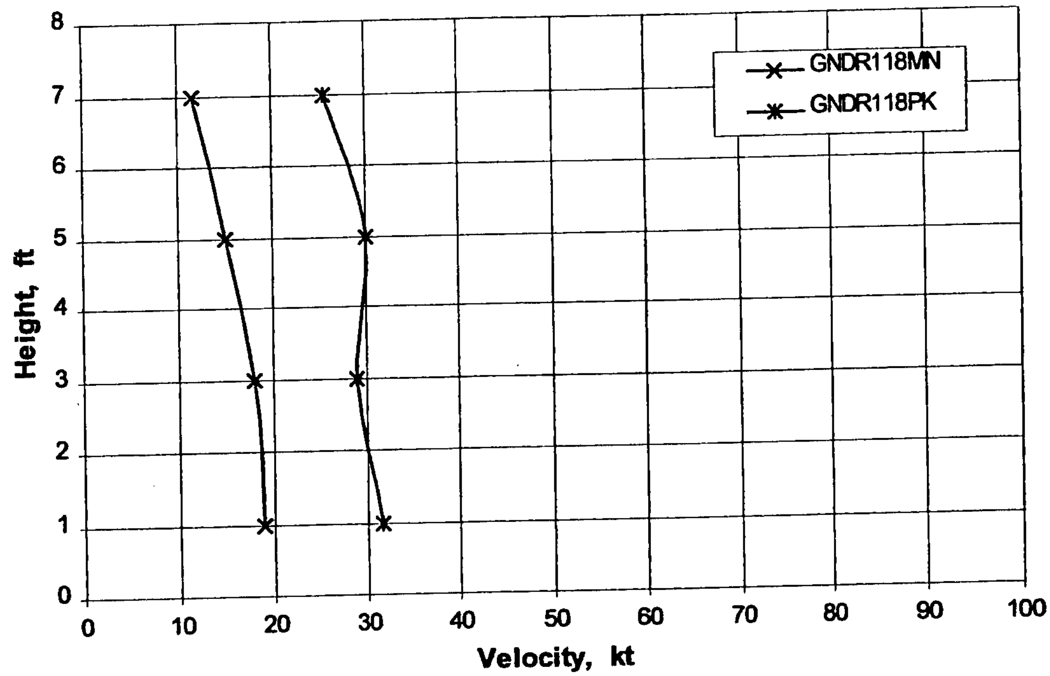


FIGURE A-3 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)

DFAC = 118 ft, HR = 21.3 ft, TR = 22,150 lb (estimated)



DFAC = 156 ft, HR = 21.3 ft, TR = 22,150 lb (estimated)

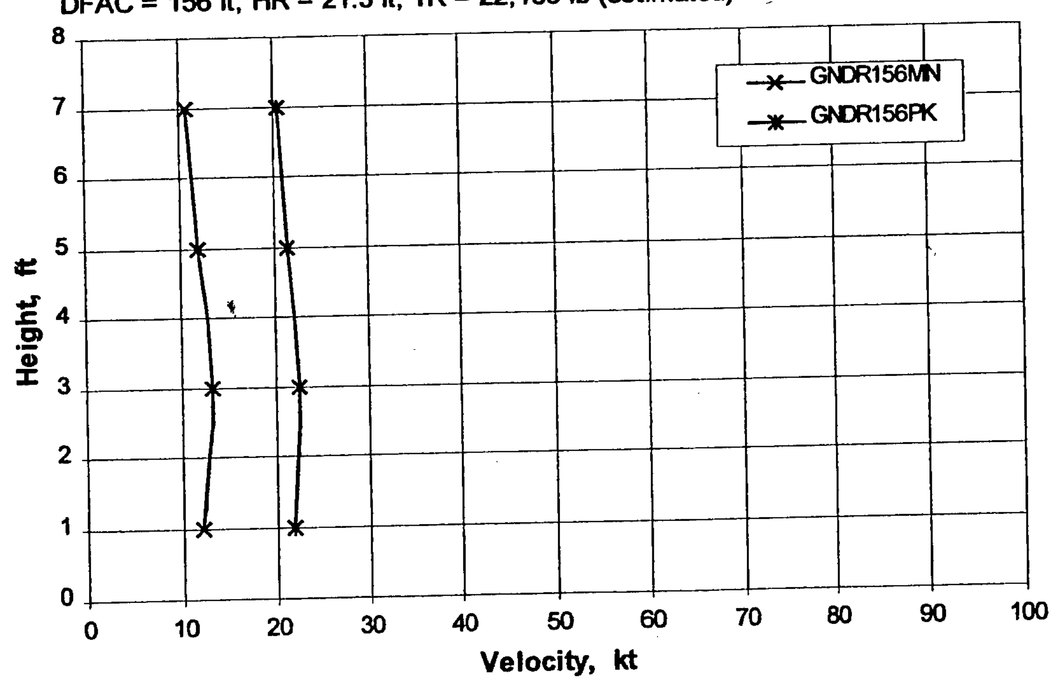


FIGURE A-3 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 100% (CONTINUED)

Notes:

V-22 A/C 8, Test 192, Records 156-164
Wind < 3 kts

Wheel Height = 0.0 ft
Rotor Height = 21.3 ft
Rotor Radius = 19.0 ft

Average Rotor Power = 644.0 SHP
Average Rotor Speed = 372.0 RPM (93%)
Density Ratio = 1.005

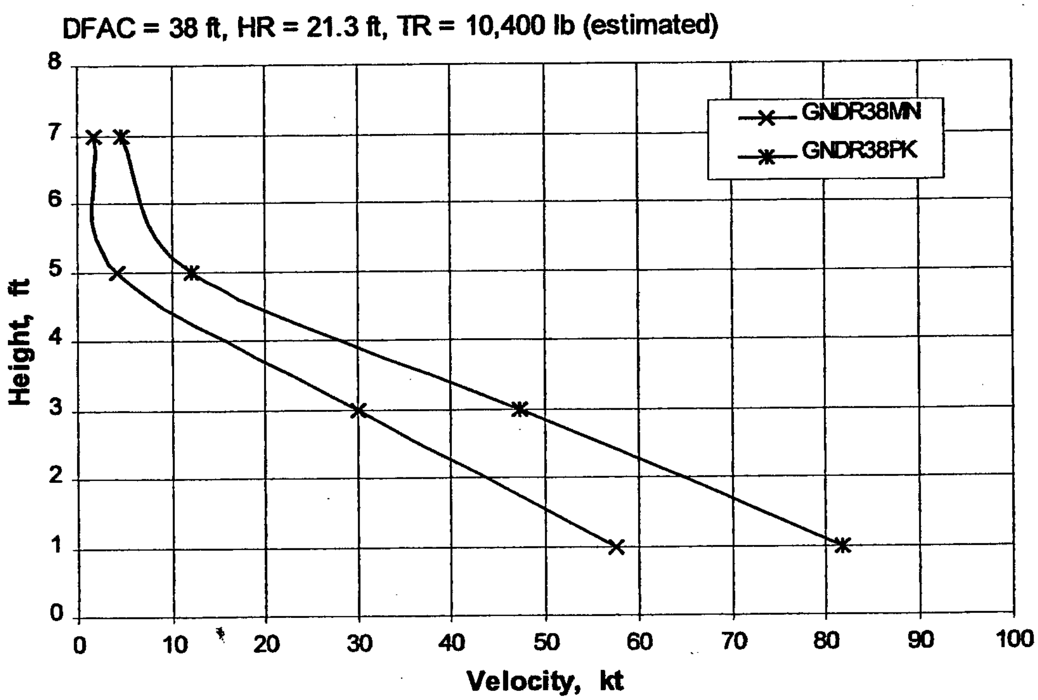
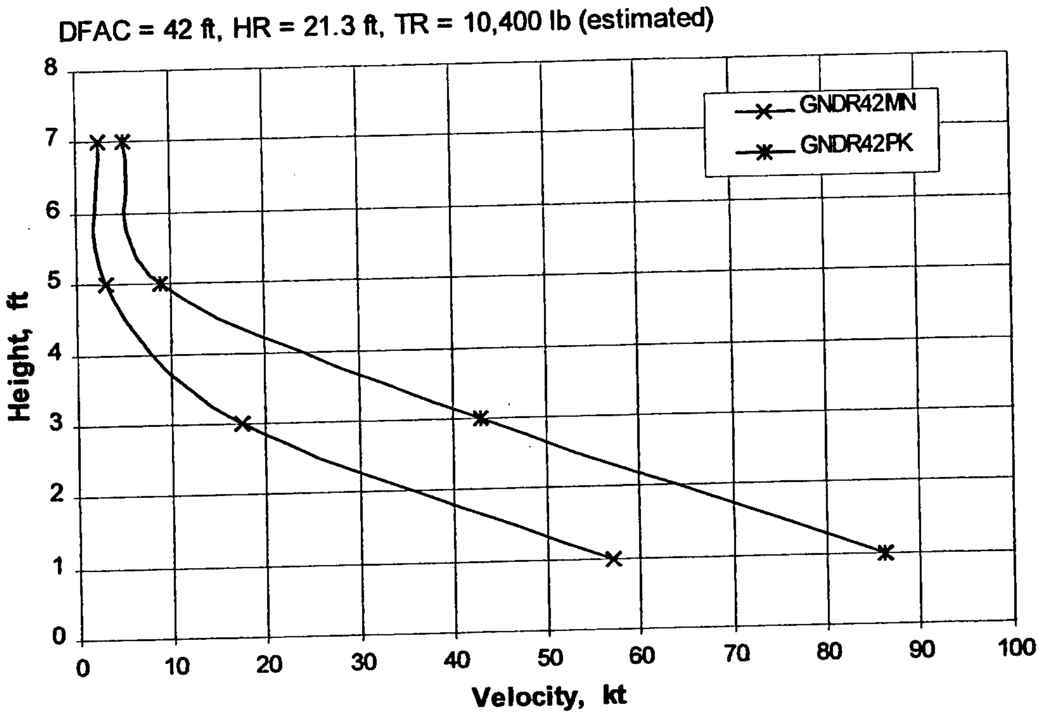


FIGURE A-4 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91%



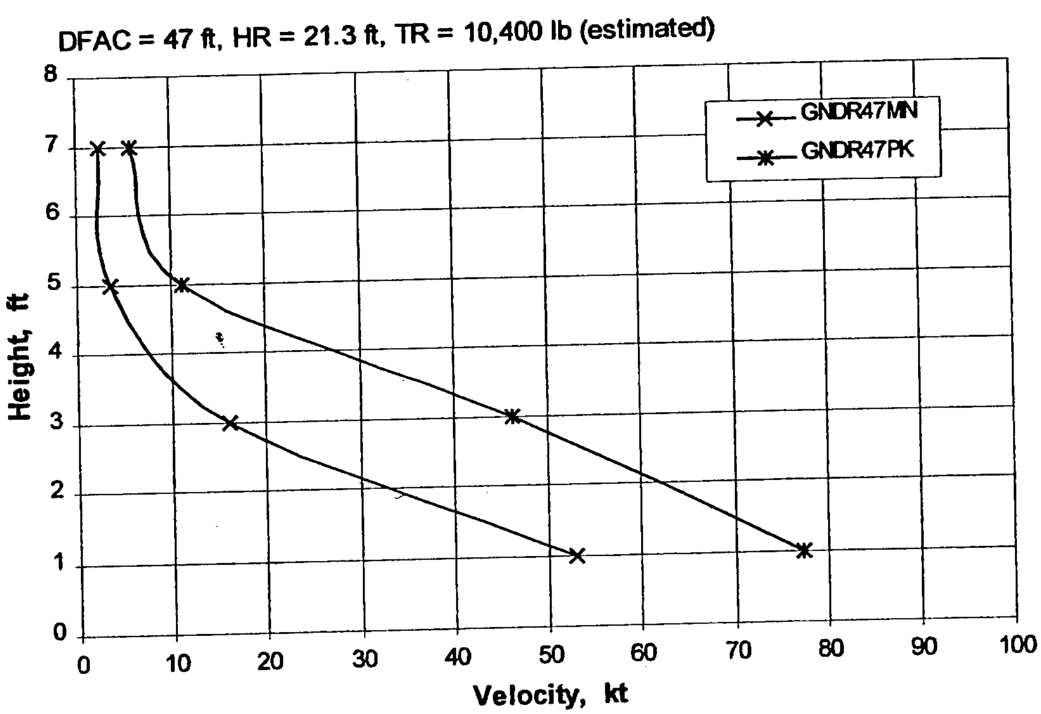
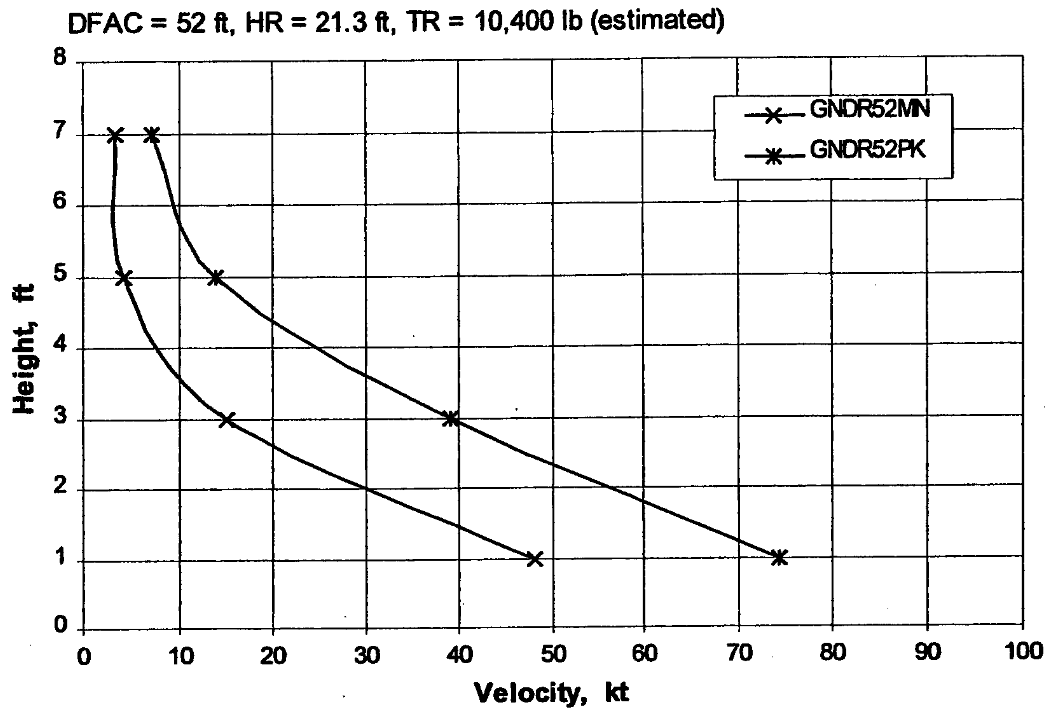


FIGURE A-4 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)



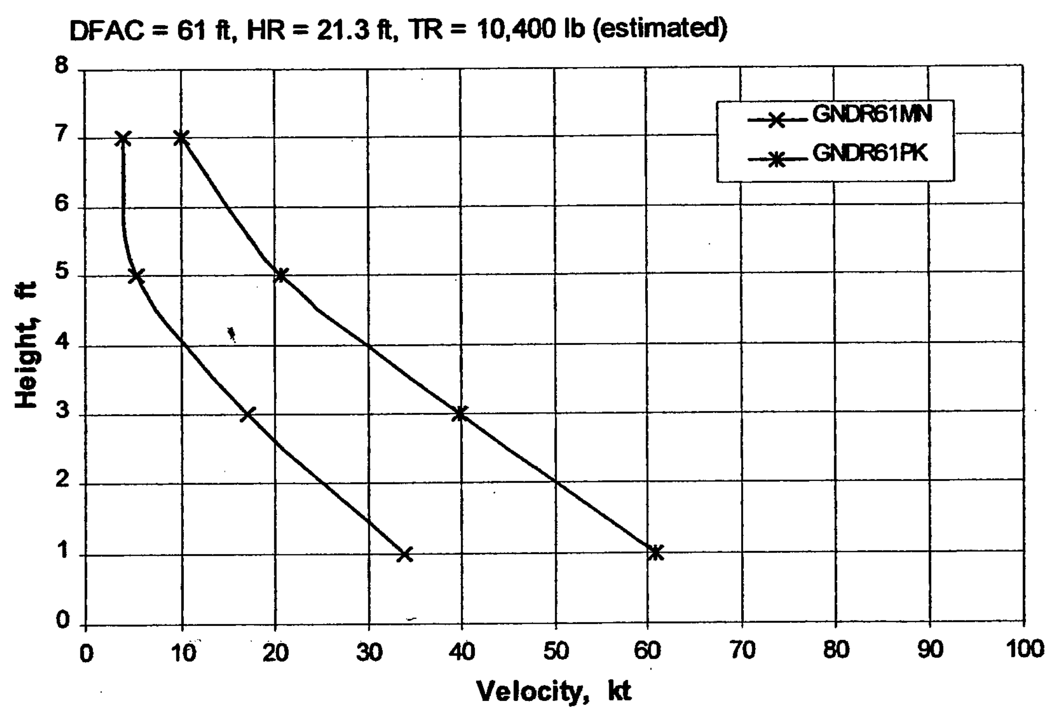
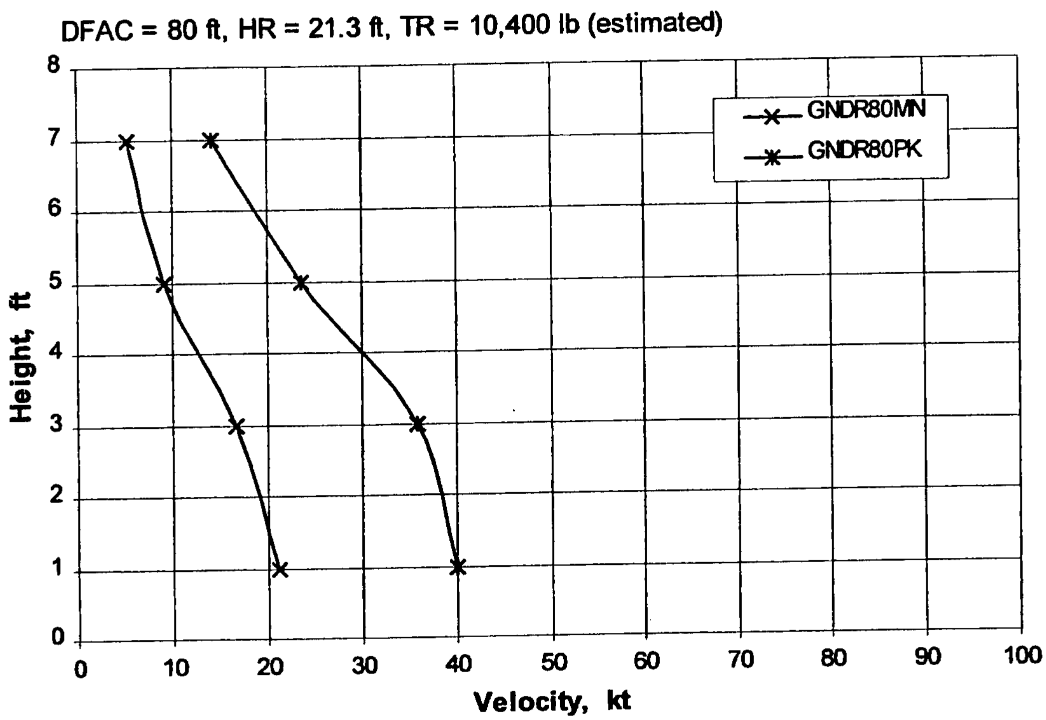


FIGURE A-4 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)



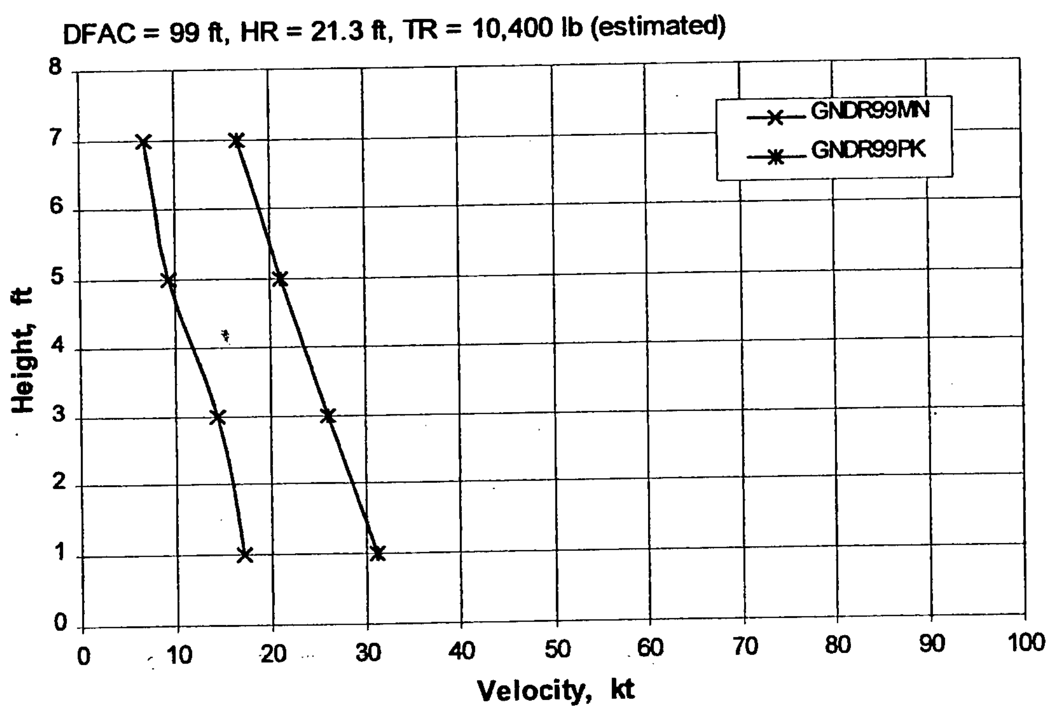
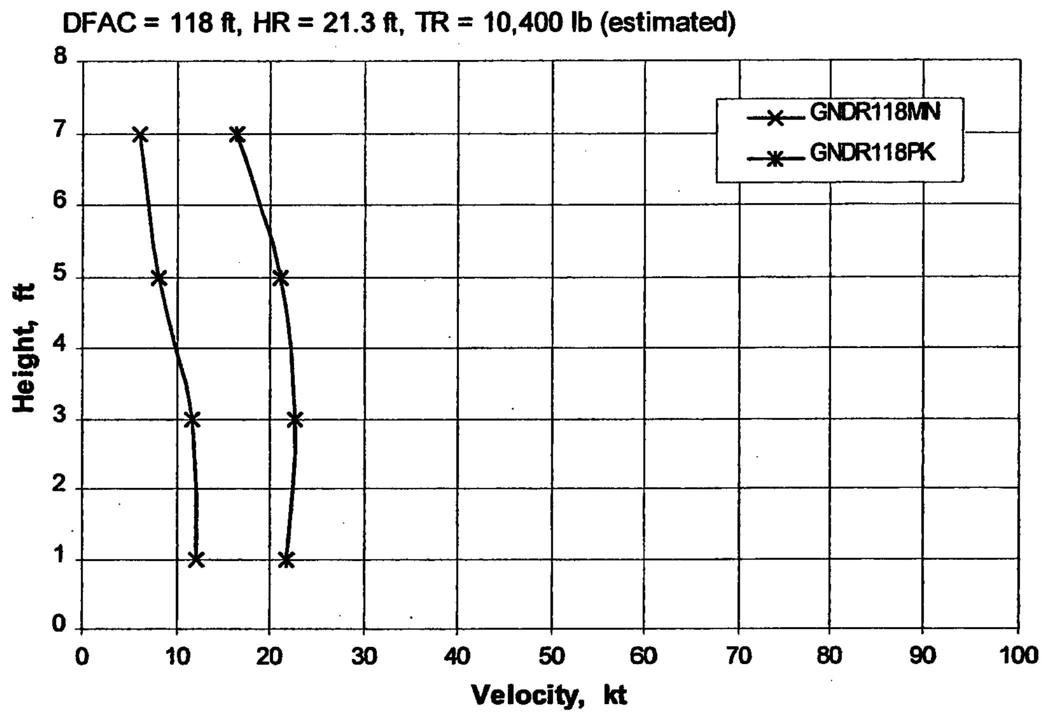


FIGURE A-4 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)



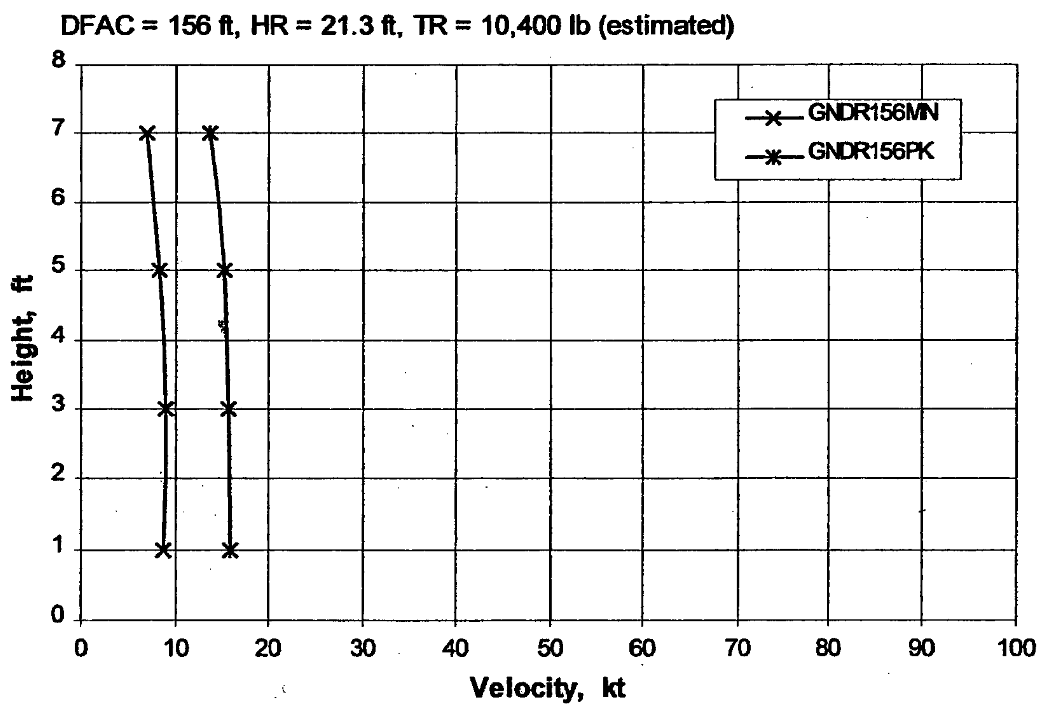


FIGURE A-4 V-22 MEAN AND PEAK VELOCITY PROFILES ALONG THE 270 DEG AZIMUTH AT A WHEEL HEIGHT OF 0 FT (ON GROUND) AND A ROTOR RPM OF 91% (CONTINUED)

Notes:

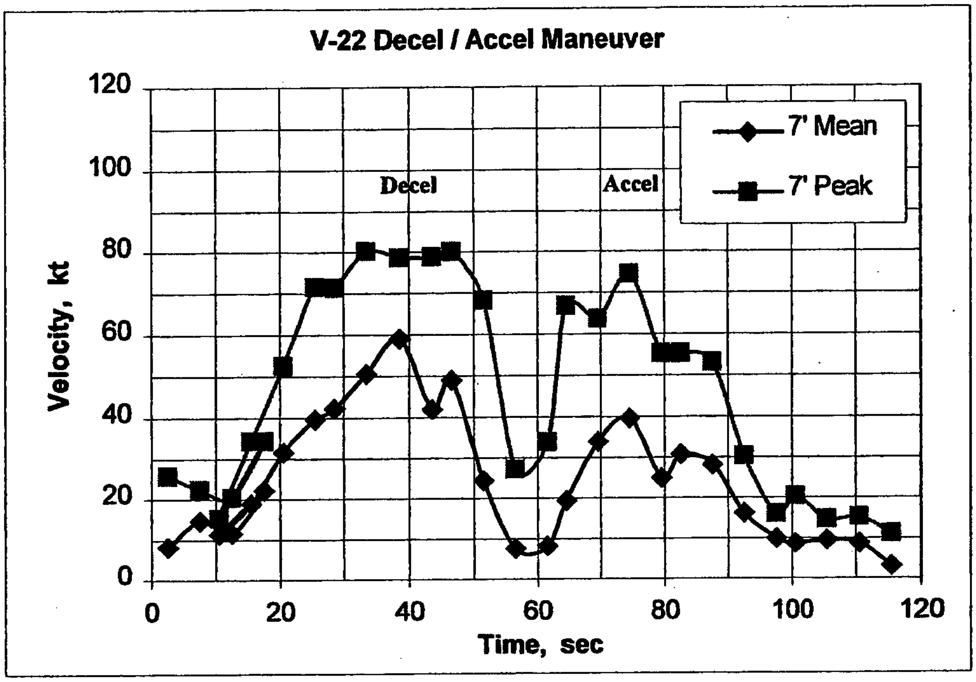
Each data point represents a 5 second time slice that is processed to extract the average velocity (mean) and the maximum peak.

V-22 A/C 8, Test 192, Records 166-168
Wind < 3 kts

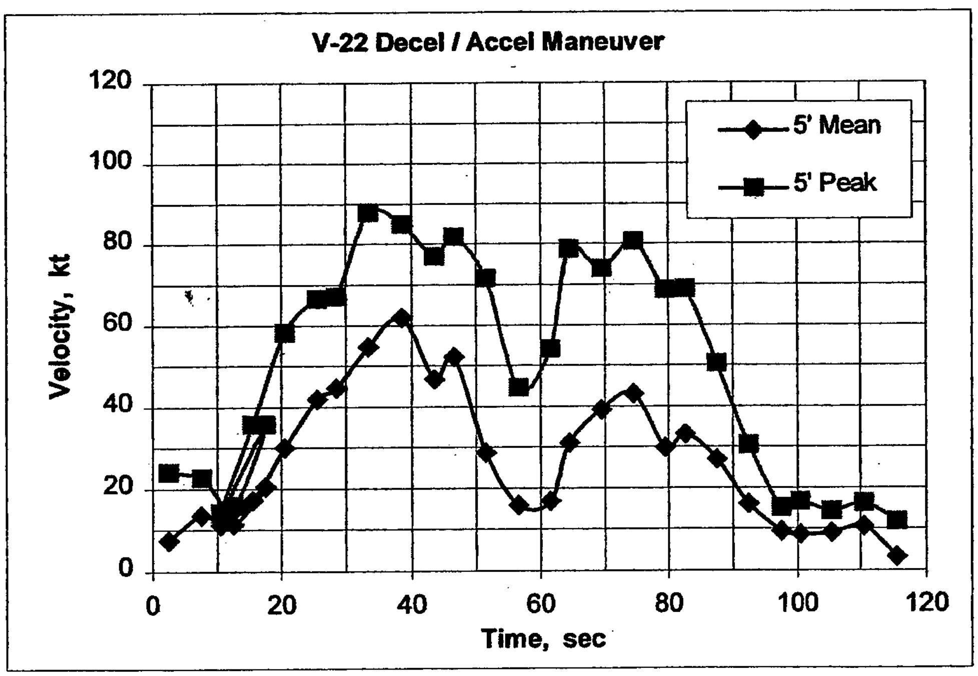
Wheel Height = 20.0 ft
Rotor Height = 41.0 ft
Density Ratio = 1.004
Rotor Speed = 100.0 %

GRAPHS ON THE NEXT TWO PAGES

FIGURE A-5 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF AN AIR TAXI DECELERATION TO A FIXED HOVER REFERENCE POSITION, FOLLOWED BY A 180 DEGREE HOVER TURN, AND AN ACCELERATION AWAY FROM THE HOVER POSITION AT A WHEEL HEIGHT OF 20 FT

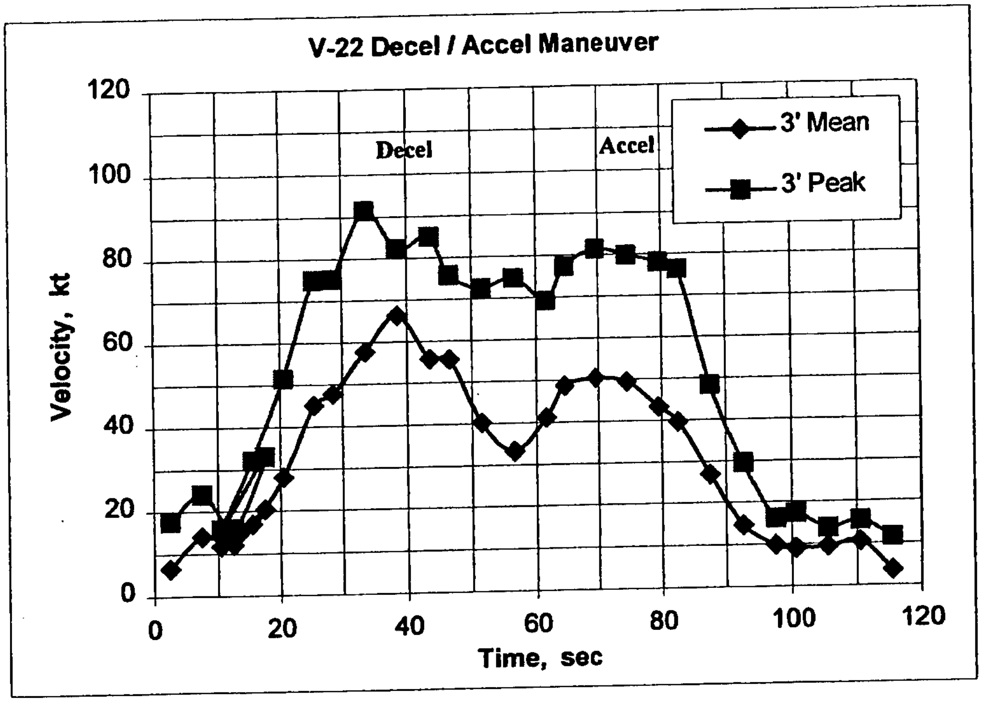


(a) Data at 7-feet AGL

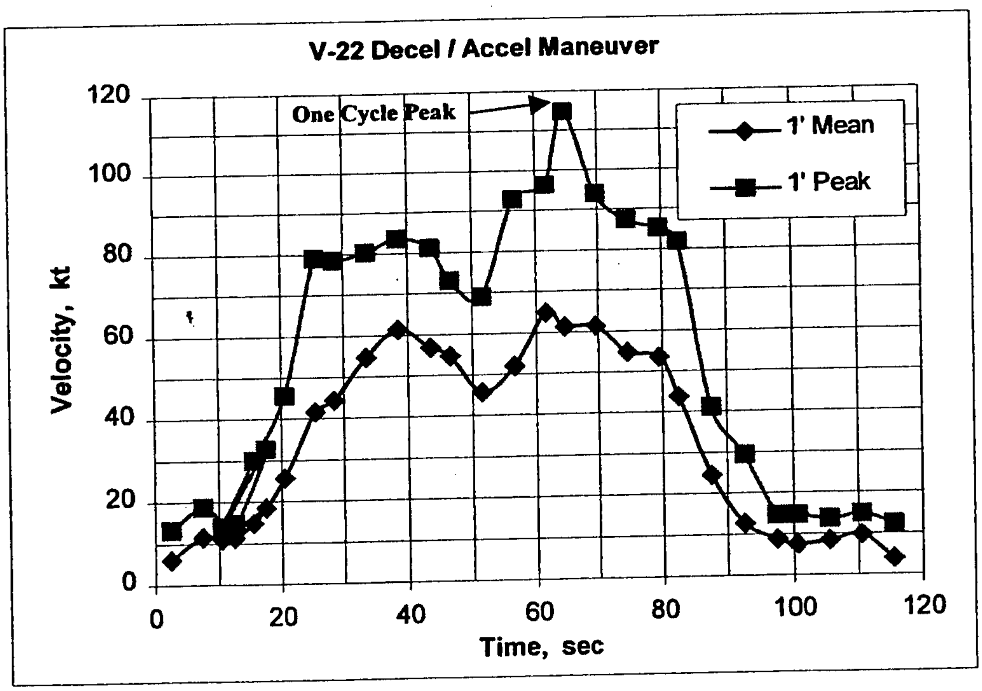


(b) Data at 5-feet AGL

FIGURE A-5 (CONTINUED)



(c) Data at 3-feet AGL



(d) Data at 1-feet AGL

FIGURE A-5 (CONTINUED)

Notes:

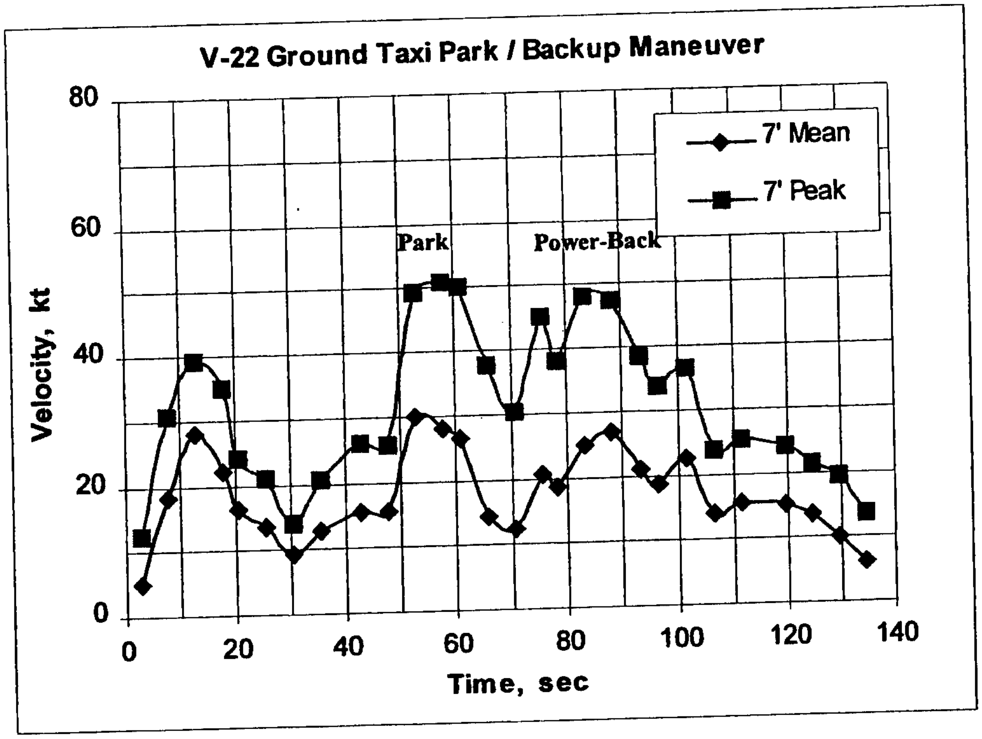
Each data point represents a 5 second time slice that is processed to extract the average velocity (mean) and the maximum peak.

V-22 A/C 8, Test 192, Records 172-173
Wind < 3 kts

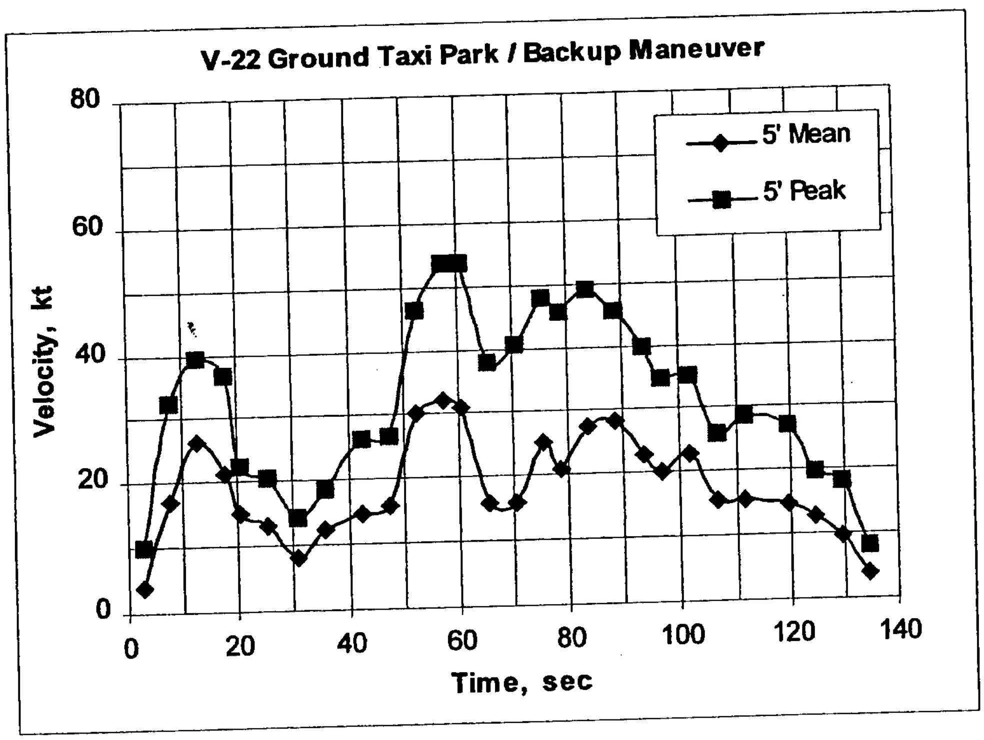
Wheel Height = 0.0 ft	Average Rotor Power = 690.0 SHP
Rotor Height = 21.3 ft	Average Rotor Speed = 378.0 RPM (95%)
Rotor Radius = 19.0 ft	Density Ratio = 1.005

GRAPHS ON THE NEXT TWO PAGES

FIGURE A-6 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A GROUND TAXI DECELERATION TO A FIXED REFERENCE POSITION FOLLOWED BY A BACKING UP ACCELERATION AWAY FROM THE REFERENCE POSITION

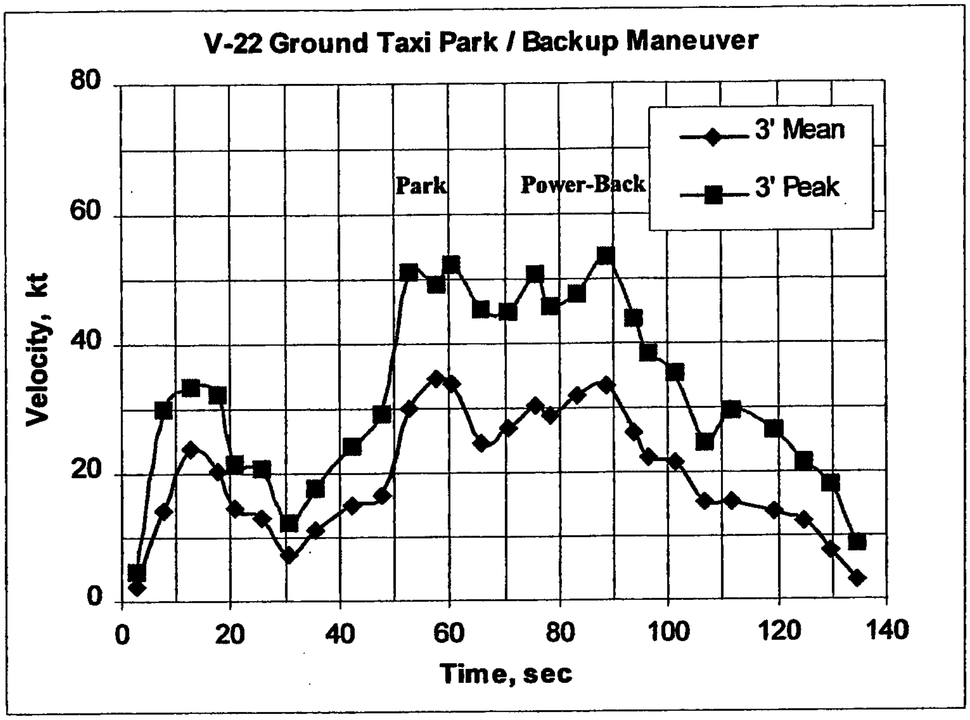


(a) Data at 7-feet AGL

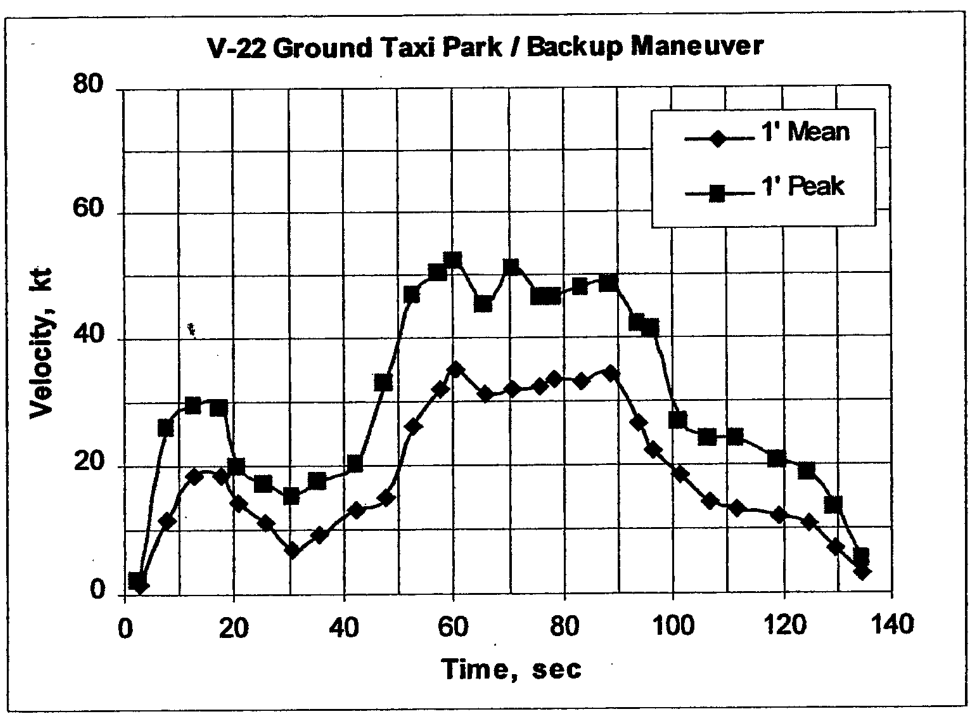


(b) Data at 5-feet AGL

FIGURE A-6 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A GROUND TAXI DECELERATION TO A FIXED REFERENCE POSITION FOLLOWED BY A BACKING UP ACCELERATION AWAY FROM THE REFERENCE POSITION (CONTINUED)



(c) Data at 3-feet AGL



(d) Data at 1-feet AGL

FIGURE A-6 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A GROUND TAXI DECELERATION TO A FIXED REFERENCE POSITION FOLLOWED BY A BACKING UP ACCELERATION AWAY FROM THE REFERENCE POSITION (CONTINUED)

Notes:

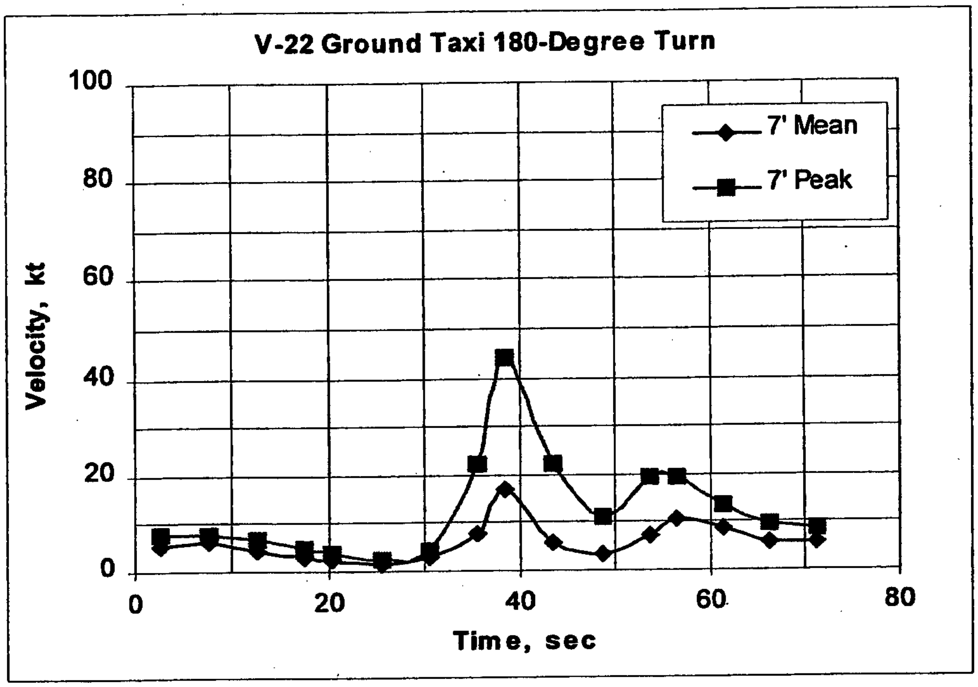
Each data point represents a 5 second time slice that is processed to extract the average velocity (mean) and the maximum peak.

V-22 A/C 8, Test 192, Records 174
Wind < 3 kts

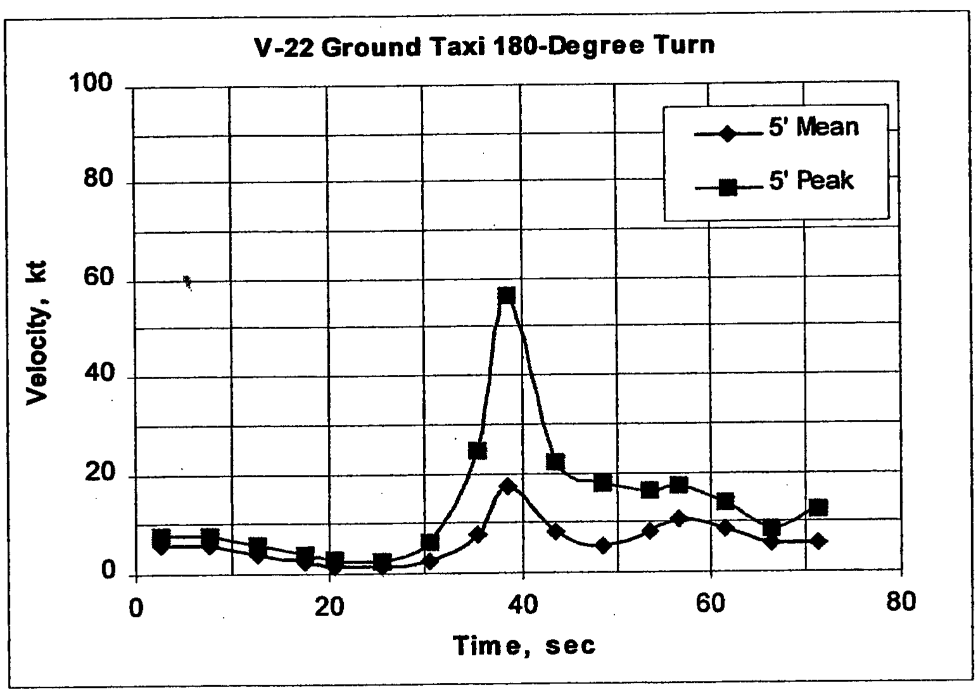
Wheel Height = 0.0 ft	Average Rotor Power = 670.0 SHP
Rotor Height = 21.3 ft	Average Rotor Speed = 373.0 RPM (94%)
Rotor Radius = 19.0 ft	Density Ratio = 1.005

GRAPHS ON THE NEXT TWO PAGES

FIGURE A-7 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A 180 DEG GROUND TAXI TURN ABOUT A FIXED REFERENCE POSITION

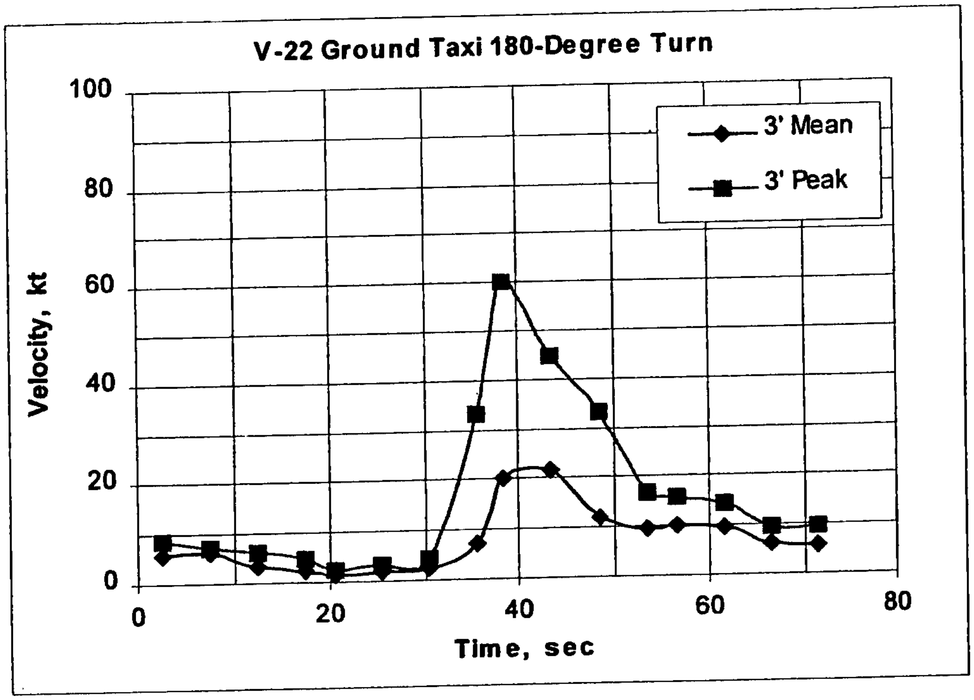


(a) Data at 7-feet AGL

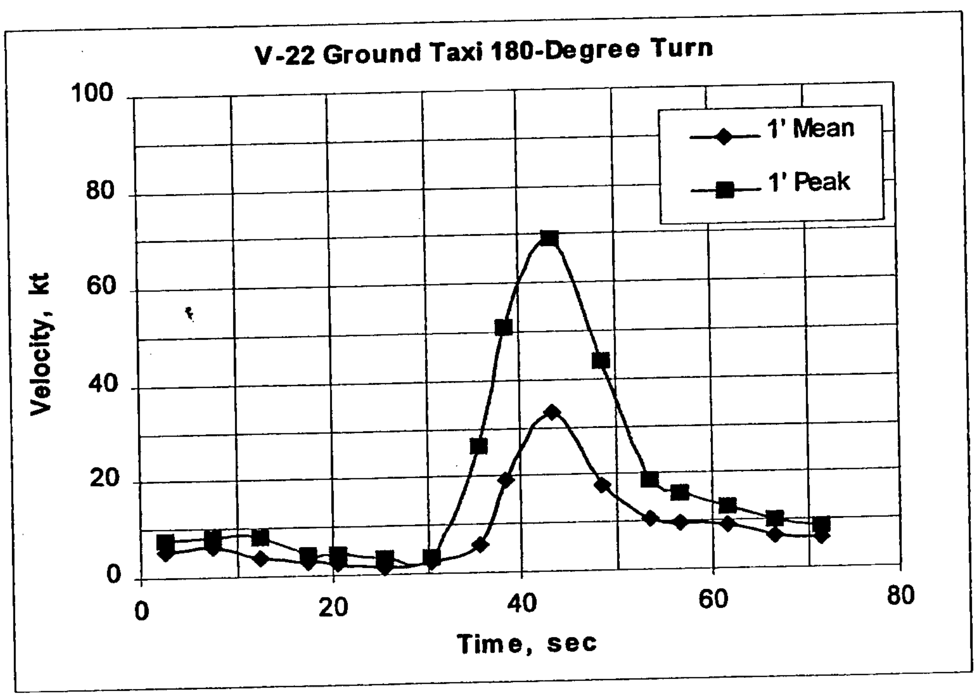


(b) Data at 5-feet AGL

FIGURE A-7 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A 180 DEG GROUND TAXI TURN ABOUT A FIXED REFERENCE POSITION (CONTINUED)



(c) Data at 3-feet AGL



(d) Data at 1-feet AGL

FIGURE A-7 V-22 MEAN AND PEAK VELOCITY TIME HISTORIES OF A 180 DEG GROUND TAXI TURN ABOUT A FIXED REFERENCE POSITION (CONTINUED)

APPENDIX B
LIST OF ACRONYMS

A/C	aircraft
AGL	above ground level (ft)
BA609	small tiltrotor under development by Bell Helicopter Textron and Augusta (Italy)
CTR	Civil Tiltrotor
DAIP	Distance Along Interaction Plane (ft)
DFAC	Distance From Aircraft Center (ft)
FAA	Federal Aviation Administration
NASA	National Aeronautics and Space Administration
NR	rotor speed (%)
R	rotor radius (ft)
RPM	revolutions per minute
SHP	shaft horsepower
S-76	medium commercial helicopter in production by Sikorsky
V-22	large military tiltrotor in production by Bell Helicopter Textron and Boeing (first flight in 1989)
XV-15	small research tiltrotor developed by Bell Helicopter Textron for NASA (first flight in 1977)

VERTIPORT DESIGN AC REVISION - WHITE PAPER
CTR ROTORWASH – HAZARD THRESHOLD FOR CIVILIAN PASSENGERS

Robert D. Smith, FAA, AND-710

August 24, 1998

Background - Source

This white paper is heavily based on Section 5 of Rotorwash Analysis Handbook, Volume I – Development and Analysis (FAA/RD-93/31,I) written by Samuel W. Ferguson under contract to the Federal Aviation Administration (FAA). Included in this paper are a condensation of some of Sections 5.0 through 5.1.8 from this handbook, additional discussion on rotorwash hazard thresholds for civilian personnel, and a discussion of some matters that postdate the publication of FAA/RD-93/31.

Interested parties are encouraged to read FAA/RD-93/31 in its entirety. For convenient comparison with Section 5 of that document, the numbering scheme (sections, figures, tables, and equations) used in this white paper is the same as that used in FAA/RD-93/31.

5.0 ANALYSIS OF ROTORWASH RELATED HAZARDS

This section describes the approach, methods, and working equations required to implement a group of rotorwash-related hazard analysis models. These models were designed as predictive tools for estimating and classifying potential rotorwash hazards as influenced by flight regime and aircraft configuration. Several of the models were developed specifically for this study; others were adapted from previous research efforts. Results calculated from these hazard models are used to define minimum safe separation distances among various aircraft of interest, various classifications of personnel, and other aircraft, structures, or vehicles.

Validation results for each hazard analysis model were presented in FAA/RD-93/31 as often as possible through correlation with available flight test, model, or previous mishap data. Data used in the original correlation analyses came primarily from flight test evaluations of the Sikorsky CH-53E, Bell XV-15, and Sikorsky S-61 (SH-3). Since the publication of FAA report FAA/RD-93/31, the FAA has obtained additional rotorwash data for both the XV-15 and the V-22. These data were collected for the following reasons:

> To ensure that the rotorwash characteristics assumed for the 9-passenger CTR (the B-609) and the 40-passenger CTR (the CTR-2000) are based on data from tiltrotor aircraft of comparable size.
>
> To provide rotorwash data with the aircraft on the ground (All previous tiltrotor data were collected with the aircraft at various distances above the ground). This is consistent with recommendations from the FAA/Industry Vertiport Design Working Group. Previous analysis has raised concerns that, during hover-taxi operations, CTR rotorwash could be so severe that excessive separations may be required to mitigate the potential rotorwash hazard. On this basis, the WG recommended that vertiports should be designed based on the assumption that all tiltrotors of all sizes will ground taxi (wheels on the ground) rather than hover taxi (hovering at an altitude within ground effect) or air taxi (hovering at an altitude above ground effect).

5.1 ROTORWASH OVERTURNING FORCE AND MOMENT EFFECTS ON PERSONNEL

In the development of any type of rotorwash-related separation criteria, the most important hazards are those that directly involve the safety and general welfare of people. Unlike buildings and equipment that can be repaired or replaced if damaged, a human that sustains serious injury (or death) precipitates a situation that will never be fully rectified, even in a court of law. Military research into personnel-related

hazards has focused primarily on quantifying requirements and developing specifications and procedures for the use of protective gear. This work has been based upon the assumption that military personnel working in a rotorwash environment are usually male, weigh at least 130 pounds, and will received at least some special hazard avoidance training. Military research has also helped to quantify parameters associated with the prediction of overturning forces and moments on personnel.

Only very limited military-sponsored research has been conducted to define what can be considered comfortable and uncomfortable to a full-size adult fully or partially immersed in a rotorwash flow field. None of this research has seriously examined the civilian side of the problem. Minimal work has been conducted to quantify what is unpleasant, uncomfortable, or dangerous to the untrained and therefore unsuspecting human (adult or child) who is suddenly either partially or fully immersed in a rotorwash flow field. Even less quantitative data exists to answer questions about what might happen to a person that is standing in or passing through such an environment while wearing a hat or skirt, carrying a purse or briefcase, or "towing" a startled or scared child.

While understandably less complete than what might be desired, this white paper is provided to answer some of the basic questions posed in the previous paragraph.

5.1.1 Background and Literature References

Personnel immersed in a rotorwash flow field are affected by a combination of factors such as the pressure forces generated by the horizontal velocity profile, the height of these forces above ground level, and the pulsating nature of the forces. It is difficult to analyze or to assess the direct effects of velocity profile data alone on personnel because:

1. velocity profile shape varies dramatically with height above ground, and

2. dynamic pressure created by rotorwash is a function of the velocity squared.

When comparing data for different flight conditions or types of aircraft, the variation in generated forces is far more meaningful from a hazard standpoint than the variation in velocity. Additionally, force data for various altitudes and gross weights generally correlate better that velocity data. This results from the fact that calculated force data somewhat filter variations in the measured peak velocity profile, whereas velocity data can only be compared directly for each corresponding height position.

Personnel forces and moments are easily calculated mathematically. However, significant procedural problems do arise when conducting the analysis itself. The first problem to be resolved is associated with choosing the "appropriate" velocity profile to convert to dynamic pressure. As has been mentioned previously, the outwash flow field is not a steady flow field by any stretch of the imagination. However, the choice of the experimentally measured peak velocity profile, instead of the statistically measured mean velocity profile, might be considered by some experimenters to be overly conservative.

A literature study indicates that use of the peak velocity profile in calculating overturning forces and moments and in quantification of safety standards is the correct choice. The literature also implies that hazardous overturning forces and moments should be termed "destabilizing" forces and moments due to their highly oscillatory nature. Literature commentary refers to the personnel hazard as one where the forces on the human body eventually become large and oscillatory. At that point, personnel can no longer anticipate and react by positioning their body to move about and work safely without being unexpectedly knocked down or overturned. Development of a standard for quantification of these dynamic forces and moments is quite different from one that might be developed for simple overturning forces and moments while in a fixed body position or for avoiding injury when moving in a fixed body position or for avoiding injury when moving directly outward to escape a potentially hazardous outwash flow field.

Laboratory experiments have been conducted in order to attempt to quantify limiting overturning force and moment values. This work quantified the levels of unexpected uniform pressure distribution that will knock a person off balance. These results indicate that a sudden change in force over 400 milliseconds will cause at least limited disorientation and unbalance when the peak uniform velocity profile creating the force is greater than 87 feet per second (51 knots). A uniform peak velocity profile of greater than 126 feet per second (75 knots) was determined to be sufficient to instantaneously unbalance and knock over a standing or walking man. However, since the research was an evaluation of a hazard that might occur following the loss of airliner cabin pressurization, it cannot be considered totally applicable to rotorwash related scenarios. As pointed out in the reference, "considerable judgment is necessary to successfully extend the experimental data beyond the limits for which it was intended." The data, however lacking, are nevertheless fully documented and referenceable.

The literature search identified a second source of experimental data to aid in quantification of practical limiting overturning force and moment values. However, before discussing this experiment, it is important to discuss another important factor. As mentioned previously, the first problem in the analysis process is to decide upon and justify using either the mean or peak velocity profile to calculate forces. A second and perhaps an even more imposing problem is the establishment of analysis criteria for personnel. For example, what size, weight, and strength percentile is to be used to model a human being for evaluating the limiting overturning forces and moments? Clearly, the physiques of an average 7-year-old child, a 25-year-old 5-foot 6-inch women, and a professional football player are vastly different, yet physique is intimately connected with the ability of each individual to overcome rotorwash-generated forces and moments. Experiments have address this second problem for military personnel actively involved in rotorcraft operations.

Laboratory tests were conducted to indirectly estimating a test subject's ability to work against rotorwash-generated wind forces. Each participant was tested to determine how much horizontal force could be pulled using a test fixture. This fixture consisted of a torso harness that distributed the load across the hips and chest to a line tied 3-feet above ground level (AGL). A weight, attached to the line, was lifted by the forward movement of the subject. Table 6 presents a list of the subject" weights and heights (percentiles are based on military statistics, not general population). Figure 70 presents a bar chart that indicates the amount of pull force that each individual was able to exert. The pull test data do not, of course, duplicate the dynamically applied rotorwash forces. However, dynamic forces were applied during the tests. These forces resulted because the slightest forward or reverse movement of the body or trunk caused the weight to move up or down. This movement of the weight required the subject to respond dynamically to the load acceleration. The limit of postural stability was taken to be the point that stability could no longer be maintained with some forward progress. The top of the black bars in figure 70 represents these postural stability limits.

TABLE 6 HEIGHT AND WEIGHT OF SUBJECTS USED IN DYNAMIC FORCE EVALUATION

SUBJECT NUMBER	HEIGHT		WEIGHT	
	INCHES	PERCENTILE	POUNDS	PERCENTILE
1	67	10th	133	2nd
2	73	90th	150	15th
3	74	95th	171	50th
4	74	95th	220	99th

Results from this postural stability laboratory experiment were used in the rotorwash evaluations of both the Sikorsky CH-53E and the Bell XV-15. Fortunately, considerable qualitative comments (i.e., ability to safely conduct work tasks within the environment) were also obtained from the test subjects that aid in

quantifying acceptable levels of rotorwash for civilian operations. Additional discussion with respect to this issue is presented in a later subsection.

5.1.2 Mathematical Modeling of Personnel

While direct measurement of overturning forces and moments would have been desired from the flight test experiments, it was totally impractical. Therefore, "experimental" force and moment calculations had to be derived indirectly using human physical dimensions, aerodynamic coefficients, and experimentally measured mean or peak velocity profile data. In returning to the results of the first experiment, it is possible to convert the 87 and 126 feet per second overturning velocities into forces and moments. The "standardized" human that was assumed in this experiment had a drag coefficient (C_D) of 1.0 and was 6 feet tall and 1.1 feet wide. Using this model, the velocities convert to 60 pounds of force for purposes of unbalance and 125 pounds for purposes of disorientation. These force values convert to moments of approximately 180 and 375 foot-pounds, respectively (at a 3-foot application height). In comparing these forces with those presented in figure 70, the calculated values appear to be quite reasonable and certainly help to provide a more documentable basis for purposes of further evaluation.

The human aerodynamic mathematical model that has been developed for this study (and incorporated in the ROTWASH program documented in FAA/RD-93/31) relies heavily upon previous work. One reference points out that values for drag coefficient (C_D) can vary significantly for humans, from slightly less than 1.0 to as high as 1.3, especially for those wearing certain types of (bulkier) clothing. Therefore, two different "standardized" yet simple humans are used in conducting the civilian-related hazard analyses presented here. These personnel are defined as:

PARAMETER	PERSONNEL TYPE	
	L	S
Height, feet	6.0	4.0
Width, feet	1.1	0.8
C_D, -ND-	1.1	1.1

where the large or "L"-sized human is similar to those previously discussed, and the small or "S"-sized human is representative of a 7-year-old child of approximately 60 pounds. A C_D value of 1.1 (not 1.0) is used as a safety factor for both sizes in the hazard evaluation process (but not in the correlation effort with test data) in order to help account for any uncertainties in the analysis process.

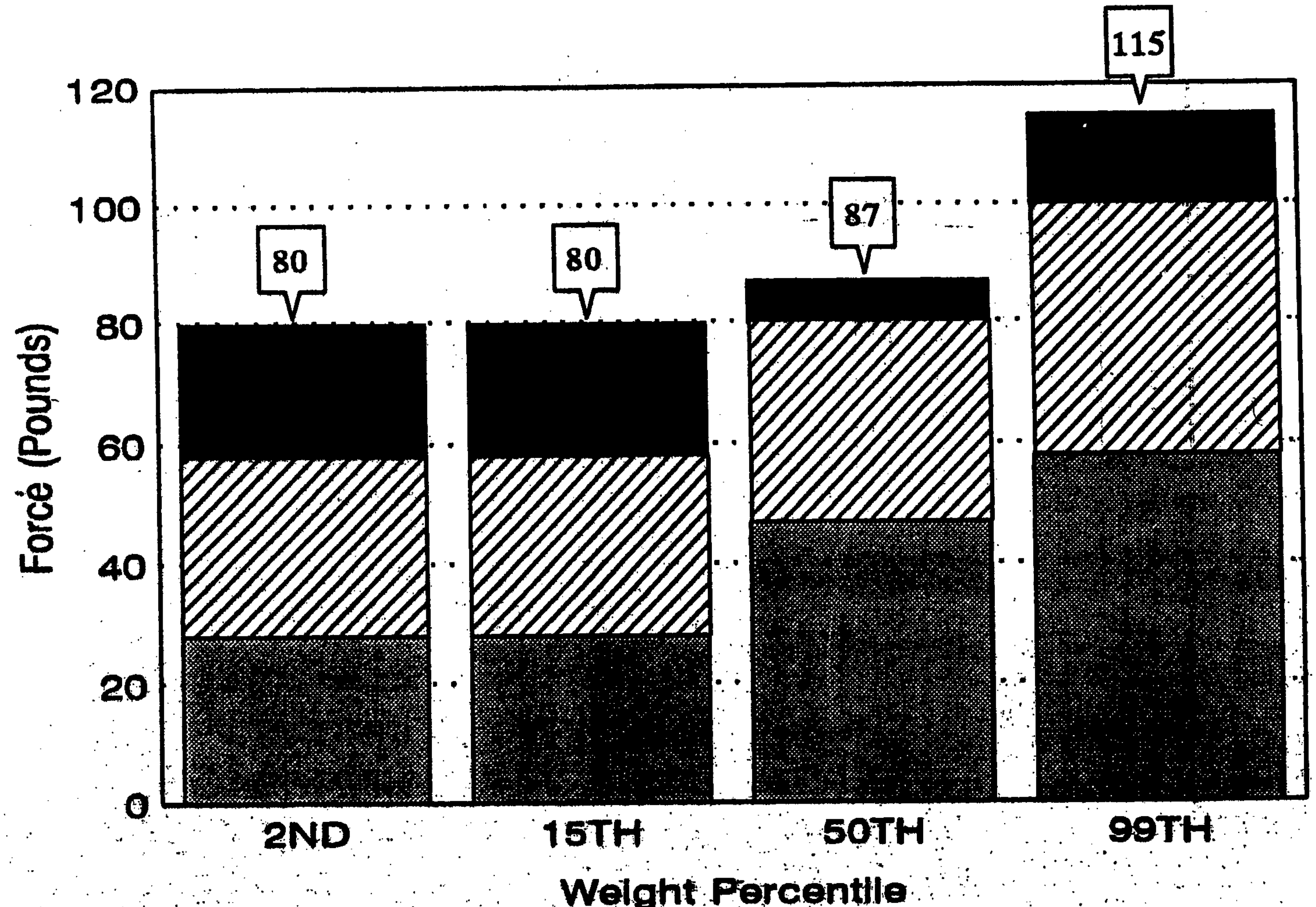
Evaluations using the human aerodynamic models are made by first calculating the peak dynamic pressure at 0.5 feet increments up to the maximum height of the subject (figure 71). This can be expressed mathematically by evaluating the equation

$$Q_{pk} = 0.5 \rho_A V^2_{pk} \quad (62)$$

where:

Q_{pk} = peak velocity dynamic pressure, lb/ft^2
ρ_A = atmospheric density, slugs/ft^3
V_{pk} = profile velocity, ft/sec

For an "L"-sized person, these pressure calculations are made at twelve vertical stations (Z_X) beginning at 0.25 feet and continuing in 0.5 foot increments up to 5.75 feet. Total force and moment are then calculated by summing each of the individual calculations made at the twelve vertical stations. The following equations are used in this process.



Limit of Forward Movement While Maintaining Stability

Difficult to Walk Forward

Relative Ease to Walk Forward

STABILITY LIMITS	
Subject	Limit
1	80 pounds
2	80 pounds
3	87 pounds
4	115 pounds

FIGURE 70 CAPABILITIES OF TEST SUBJECTS TO MOVE ABOUT WITH HORIZONTAL RESTRAINT LOADS APPLIED AT 3-FEET AGL

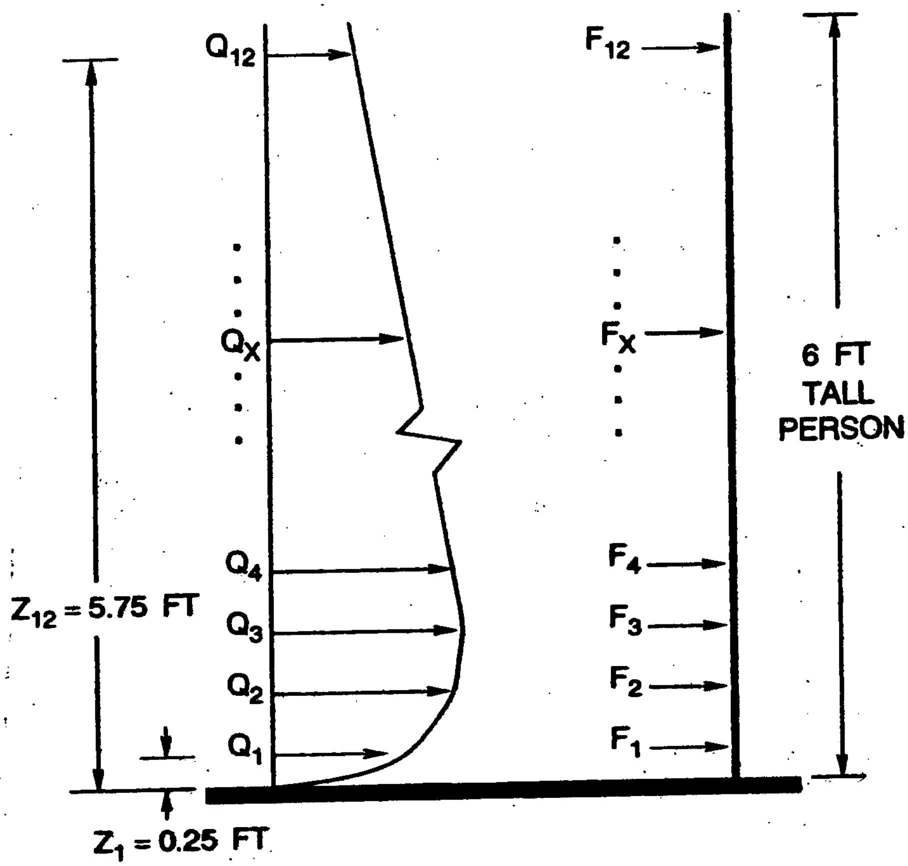


FIGURE 71 GRAPHICAL DEFINITION OF OVERTURNING FORCE AND MOMENT CALULATION PROCEDURE

$$F_{pk} = \sum_{X=1}^{12} (Q_{pkx})\,(C_D)\,(W_h)\,(\Delta H) \qquad (63)$$

$$M_{pk} = \sum_{X=1}^{12} (Q_{pkx})\,(Z_x)\,(C_D)\,(W_h)\,(\Delta H) \qquad (64)$$

where:

C_D = human drag coefficient, -ND-
W_h = width of the human, ft
ΔH = incremental vertical height for evaluation, feet (in this case 0.5 feet)

In the case of the "S"-sized person, the same analysis methodology is used. However, the value of x is evaluated at only eight vertical stations (ending Z_x at 3.75 feet).

With definition of the personnel model now completed, it is possible to evaluate potential personnel-related hazards using the rotorwash models. However, before this task is conducted, it is very important to correlate calculated data from the mathematical model with available flight test data to validate the analytical approach.

5.1.3 Quantitative Validation with Experimental Data

Experimental force and moment data, based on flight test velocity profiles, were identified from several sources for validation purposes. CH-53E, XV-15, MV-22, and SH-3 data were used as validation data.

Results from this comparison for both forces and moments indicated that the data correlate reasonably well in the far field for an assumption that the ambient wind is approximately 3 knots. If the wind is assumed to be zero, calculated values over-predicted the flight test data. However, these results should not have been unexpected because a mechanical sensor was used to measure the velocities used to compute forces. Research has shown that the use of such sensors results in lower than actual measurements of both velocities and forces. The test report indicated that the ambient wind varied from approximately 0 to 4 knots.

5.1.4 Qualitative Evaluation of Experimental Data

Quantitative data provide guidance for calculation and correlation of overturning forces and moments. However, these types of data do not provide guidance as to what may or may not be an acceptable level of rotorwash in association with civilian tiltrotor or helicopter operations. Furthermore, definition of acceptable rotorwash levels for civilian operations is itself somewhat ill-defined. What may be acceptable and safe to a heliport or vertiport ramp employee would be considerably different from that considered acceptable by an embarking business executive, a senior citizen, a disabled person, or a 7-year-old child. Therefore, before making an assumption that a certain level of overturning force or moment is acceptable for civilian operations, such as the 80 pound level in figure 70, it is important to review some of the available qualitative data that have been reported.

Qualitative comments provided by subjects 3 and 4 (figure 70) following the CH-53E test at the 45,000- and 56,000-pound gross weights agree well with quantitative predictions and the laboratory test results used to construct figure 70. At the 45,000-pound gross weight, subjects 3 and 4 experienced only minor difficulty while working in rotorwash with the aircraft at a 37-foot hover and no difficulty at the 77- and 117-foot hover heights. However, the forward movement of subject 3 was completely restrained near the position marked 80 feet (from the center of the test site) during the 37-foot hover at 56,000 pounds. During the 77-foot hover, subject 3 could maneuver in the peak force region with some difficulty. Subject 4 could maneuver in all regions of the flow field during the 56,000 pound test; however, he did experience difficulty while working in the peak force region during the 37-foot hover. Subject 4 also participated in a qualitative survey during the 70,000 pound gross weight evaluation. While he was able to completely penetrate the flow field at all three hover heights, he did experience great difficulty when moving in the peak force region, and postural stability could not be controlled.

Further work with the CH-53E at 42,625 and 50,664 pounds and with an RH-53D at 40,950 pounds was conducted along with the evaluation described in the previous paragraph. Each of the four subjects listed in table 6 participated in the qualitative analysis portion of the test. Subjects 1, 2, and 3 indicated that the strength of the outwash flow fields for both helicopters made it difficult to maintain balance, and the forces were disorienting even at the lower disc loading (42,625 pounds) for the CH-53E. However, no major differences in the degree of difficulty required to maneuver in all three flow fields were reported. In general, all four subjects considered the RH-53D to have a more periodic and predictable pulsation, thus requiring continual compensation in order to maintain postural stability. Steady-state CH-53E flow field pulsations were not as easily identified. However, there were time periods between pulsations involving large gusts that were possibly caused by the automatic flight control system (AFCS). Compensation for these sudden unexpected gusts required even more caution and alertness.

During RH-53D and CH-53E tests at equivalent disc loadings (40,950 and 50,665 pounds, respectively), subjects 1 and 2 had to exert extreme effort, while maintaining only limited balance, in order to penetrate the maximum force region. Subject 3 could penetrate and maintain balance at these equivalent disc loading test points; however, subject 3 was unable to penetrate the maximum velocity region (80 feet from rotor

center) during qualitative testing of the CH-53E at the 56,000- pound weight. Based on both of these sets of qualitative and quantitative data, it was concluded that the CH-53E is no more hazardous than the RH-53D at a similar disc loading. It is also indicated from the qualitative results that up to the 50,000-pound gross weight configuration, the flow fields are tolerable for trained military personnel.

The CH-53E gross weight of 56,000 pounds presented difficulties to personnel over a wide range of weights and strengths that ranged from complete instability (very high hazard potential) to marginal instability (high hazard potential). It is therefore concluded that a CH-53E at a 50,000-pound gross weight produces the maximum forces and moments to which trained personnel should be exposed without restricting their distance from the center of the aircraft.

It is also important to note that qualitative observations by the subjects during the tests were made under optimum conditions; the only task required during these tests was to walk completely through the flow field. The ground surface was rough concrete (for best traction) and the helicopter was not moving so that the subjects could approach the flow field at their own pace. Therefore, for civilian purposes, one might conclude that the peak force levels (approximately 80 pounds) experienced at the lower CH-53E disc loading (42,625 pounds) are the maximum allowable for large adults. This is because other variables would have to be taken into account when analyzing the rotorwash hazard potential as extrapolated to other classes of personnel. These variables would include factors such as age, size, weight, strength, endurance, and reflex response when subjected to the rotorwash. Environmental considerations such as the traction offered by the ground surface, loose foreign objects and grit, the difficulty of the task to be performed (in the flow field), and whether or not the aircraft is moving are also factors that require attention.

Qualitative tests were also conducted with the XV-15 at rotor heights of 37.5 and 62.5 feet using subject 4 (table 6 and figure 70). The path that test subject 4 traversed and the locations where he stood, both into and away from the flow direction, are sketched in figure 84. Test subject 4 reported no problems walking or standing under the XV-15 even though his forward movement was slightly impeded by the flow field. This test subject had the most difficulty along the 0- and 180-degree azimuths, and he noted that the flow magnitude was composed of frequent large wind gusts. Neither the test subject nor observing test personnel noticed any differences in relative difficulty due to the variation in hover height. In summary, the limited qualitative observations are in good agreement with the quantitative force data as previously presented and correlated. While no quantitative data were obtained under the XV-15 within a 26-foot circle (centered about the XV-15 center), test subjects indicated that forces in this area were comparatively low. Observations by test observers and movies also indicated that velocities in this central region are relatively low in magnitude during a hover. Test personnel were observed to walk erect and relaxed in this region.

TABLE 8 PERSONNEL LIMITATIONS IN XV-15 FLOW FIELD REGIONS

	WEIGH IN POUNDS (PERCENTILE[2])		
REGIONS[1]	150 Pounds (25th)	171 Pounds (75th)	220 Pounds (99th)
I	Exceeds stability limit, hazardous.	Difficult to walk through region.	Slightly difficult to walk through region.
II	Very difficult to walk through region.	Slightly difficult to walk through region.	No difficulty to walk through region.
III	Moderately difficult to walk through region.	No difficulty to walk through region.	No difficulty to walk through region.
IV	No difficulty to walk through region.	No difficulty to walk through region.	No difficulty to walk through region.

Notes: (1) These Regions are defined in figure 85.
(2) These percentiles refer to the population of military personnel, not to the general population.

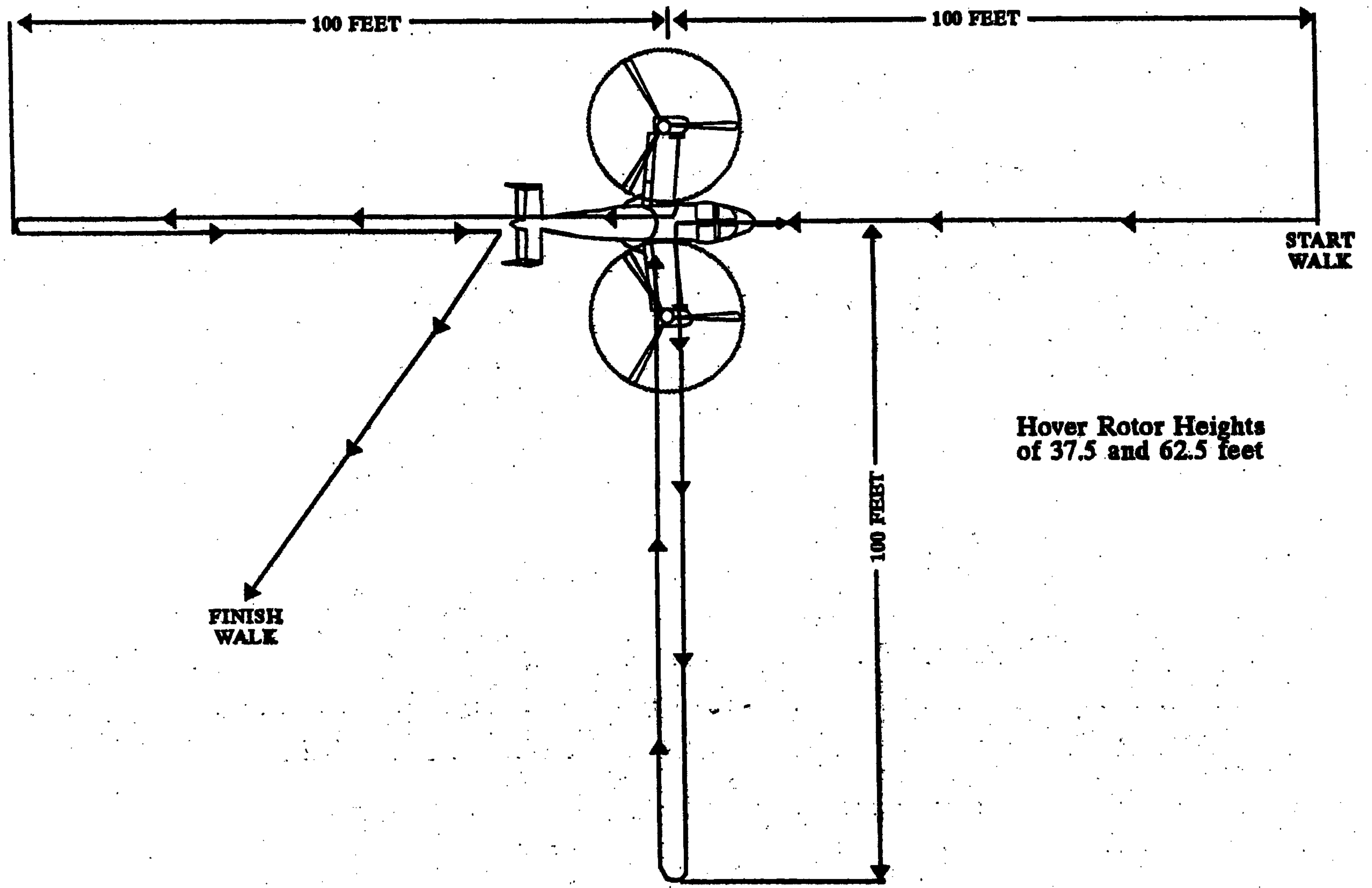
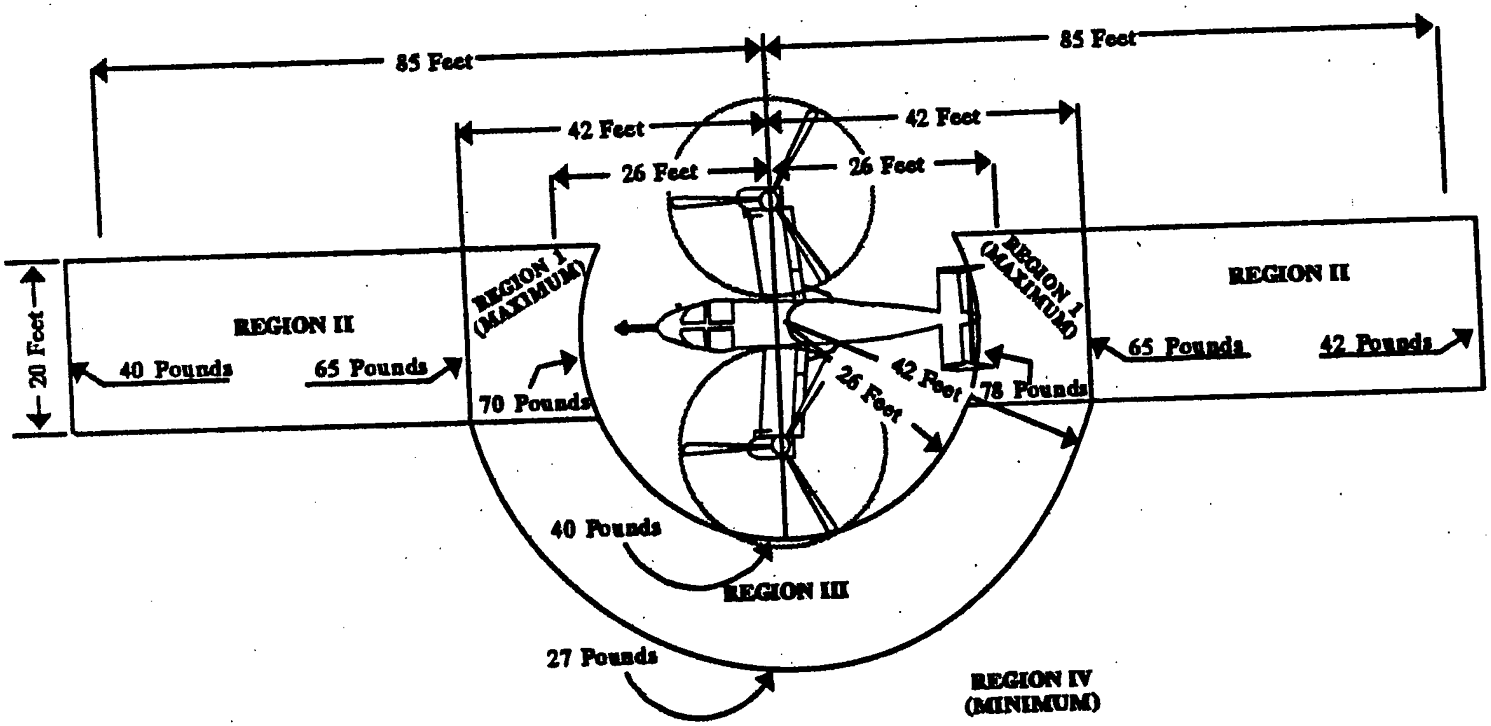


FIGURE 84 QUALITATIVE WALK THROUGH EVALUATION OF THE XV-15 ROTORWASH FLOW FIELD AT ROTOR HOVER HEIGHTS OF 37.5 AND 62.5 FEET



NOTE: Description of level of force in each region is contained in Table 8.

FIGURE 85 REGIONS OF OVERTURNING FORCE GENERATED BY THE XV-15 ON GROUND PERSONNEL

Figure 85 summarizes XV-15 outwash forces by presenting the data as four regions that define distinct degrees of difficulty for personnel trying to maintain stability. The degree of difficulty relative to each region, based on the quantitative criteria in figure 85, is presented in table 8. Based on these results (even though limited in scope), it can be assumed that the majority of regions III and IV present no significant problems to adult personnel walking, standing, or performing limited work over the range of XV-15 test conditions. In contrast, regions I and II do have the potential to be hazardous to humans weighing less than 150 pounds (25^{th}) weight percentile). In studying these qualitative data further, it can be hypothesized that, the 40 pounds of overturning force in region III represents the maximum to which civilian adult passengers should be exposed.

5.1.5 Overturning Force and Moment Limits for Civilian Operations

Quantification of safe separation distances for civilian personnel requires the specification of hazardous force and moment levels. Results from the previous subsections are combined in figure 86 into a usable format for comparison purposes to start this task. This comparison is an expansion on the database presented in figure 70. Combining the data in figure 86 with the comments in table 8, the following limits in table 9 are proposed for tiltrotor operations involving non-military personnel.

TABLE 9. FORCE AND MOMENT GUIDELINES FOR CIVILIAN OPERATIONS

Personnel Classification	Force Limit, 1b	Moment Limit, Ft-1b
I: Trained and protected ramp personnel Who work frequently in a rotorcraft downwash environment	80	120
II: Untrained and unprotected personnel Who are rarely or never exposed to a rotorcraft downwash environment	40	120
III. Untrained and unprotected children Walking without adult assistance in a Rotorcraft downwash environment	30	60

While these limits appear practical and reasonable, based on the limited available data, it would be premature to conclude that these are the best limits that could be derived if the force and moment database were more extensive. (A test plan has been developed for testing civilian personnel rotorwash hazard thresholds but no testing has been done.)

Limits specified for unaided children are derived from the extrapolation of table 6 and figure 86 data and are presented in figure 87. Several children were measured and weighed for this study in order to provide a rough estimate for developing the "S" type person (or 7-year-old child) model in section 5.1.2, as well as for aiding in the rough calculation of a force and moment limit. Based on the military test results, body weight is judged to be the most important scaling parameter for defining a force and moment limit. Moment calculations for a child ("S" type person) are based on an application point of two feet versus the adult value of 3 feet.

It should be noted that the limits of Table 9 consider only overturning forces. Other safety considerations should also be considered in making judgments on how close passengers might be allowed in the vicinity of aircraft with rotors turning.

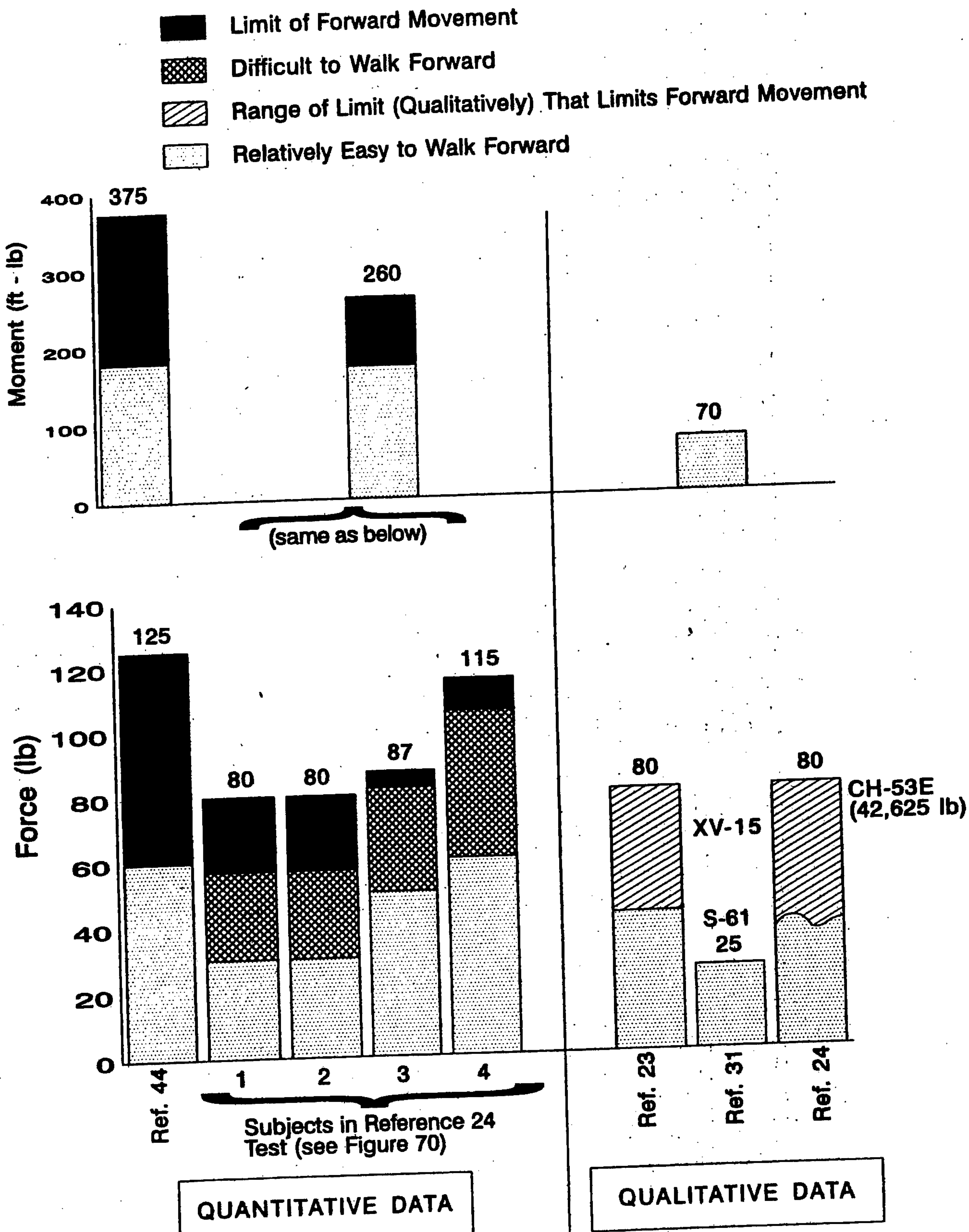


FIGURE 86. SUMMARY OF QUANTITATIVE AND QUALITATIVE DATA ON LIMITING VALUES OVERTURNING FORCE AND MOMENT

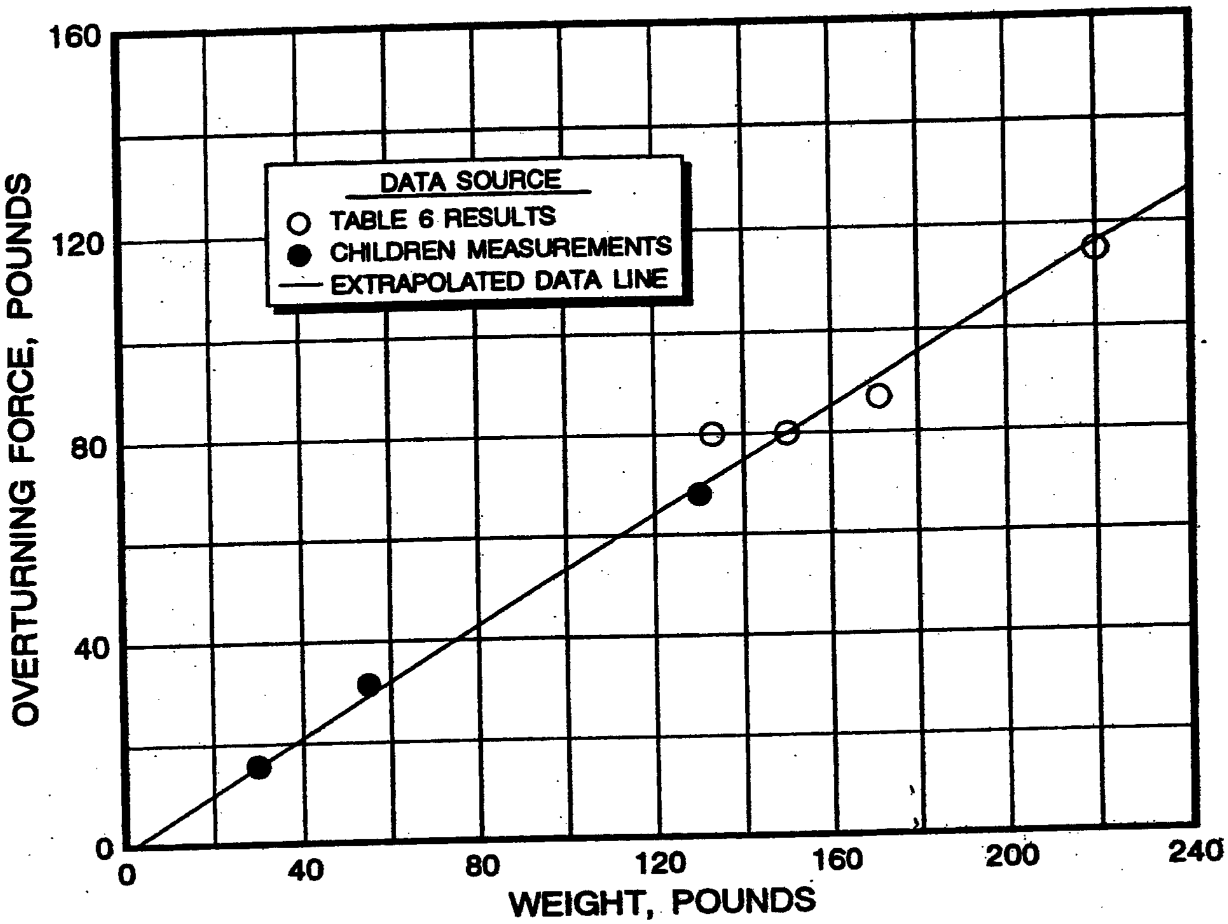


FIGURE 87 EXTRAPOLATION OF EXPERIMENTALLY MEASURED OVERTURNING FORCE DATA TO LIGHTER WEIGHT CLASSES OF PERSONNEL

5.1.8 Summary of Personnel-Related Overturning Force and Moment Hazards

This white paper describes an analysis methodology for evaluating the hazard potential of overturning forces and moments on personnel who are exposed to aircraft downwash/outwash flow fields. This analysis methodology is based on correlation with both laboratory experiments and flight test results (both qualitative and quantitative) for several different aircraft. Safety factors are identified in the analyses whenever they are used to account for discussed uncertainties. Experiments have been proposed that might improve the quantification of safety factors as well as limiting values for overturning forces and moments that are applied to unprotected and untrained civilian personnel. However, these experiments have not been conducted.

This methodology and the threshold values discussed can be used to develop separations between people and CTR with rotors turning. Larger separations are appropriate for the protection of civilian passengers than for the protection of trained ramp personnel. Larger separations are appropriate for the protection of child passengers than for the protection of adult passengers. The FAA is particularly concerned about the

separation required to keep a civilian passenger from losing balance, falling, and perhaps being injured. Industry can choose from several methods of addressing this issue. These have been addressed in previous WG white papers (**Vertiport Terminal Gate Separations** dated April 22, 1997 and **CTR Rotorwash Effect on Civilian Passengers** dated April 22, 1997)

Tiltrotor operators may find that the market place requires them to be concerned about issues of passenger comfort in the presence of rotorwash during passenger boarding and deplaning. These could include rotorwash effects on the passenger wearing a hat, the lady wearing a skirt, the passenger who is hand-carrying tickets or other loose papers, and the passenger wearing contact lenses who is concerned about rotorwash-blown sand in her eyes. Passenger comfort issues would present a more demanding requirement than the safety issues addressed above. Still, Industry can choose from several methods of addressing this issue. These have also been addressed in previous white papers (**Passenger Loading Bridges and Passenger Comfort** dated April 22, 1997 and **Accessibility to Individuals with Disabilities or Special Needs** dated April 22, 1997).

References

FAA/RD-93/31,I **Rotorwash Analysis Handbook: Volume I - Development and Analysis**

FAA/RD-93/31/II **Rotorwash Analysis Handbook: Volume II - Appendixes**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
COMMUTER AIRCRAFT RAMP AND PASSENGER SAFETY PRACTICES
Possible Application to Tiltrotor Aircraft

Raymond A. Syms, Aeronautical Consultant

May 27, 1998

The safety of ramp personnel and passengers on airport ramps is an on-going concern to all parties involved. Literally thousands of injuries and some deaths have been prevented by learning from past mistakes. The possible application of this valuable experience to Tiltrotor applications is the subject of this paper.

It is envisioned that a segment of the Tiltrotor usage will be in commuter, corporate and private air transportation that will use airports and conventional airfield ramps. Therefore an understanding of the current commuter turboprop airplane safety procedures in use including passenger handling techniques is essential for the possible application of these experiences to Tiltrotor operations.

The inventory of ramp safety procedures started with Newark Airport, Newark, New Jersey. The airport is owned and operated by the Port Authority of N.Y. & N.J. The day-to-day ramp area movements and safety are however the responsibility of the using airline. This division of responsibility is common throughout the air carrier airport system.

Phone interviews with the ramp operations managers of Continental and United Airlines commuter air carriers at Newark Airport took place. The procedures in use at Newark Airport are very simple, consistent, and verified by multiple observations. **When there is a propeller turning, there are no passengers allowed to be boarding or deplaning from other aircraft within approx. 200 feet.** An aircraft can board or deplane passengers when the propeller on the opposite side of the aircraft is running, however, sufficient airline personnel are needed to assure no passenger can divert from the direct line to the terminal or the bus. When an aircraft is departing or arriving at the ramp, there are no passengers on the ramp unless they are in an aircraft, bus or boarding vehicle. The airline personnel are trained and monitored to ascertain that their actions and placement during these same times are consistent with their airlines safety practices.

In order to ascertain if there were other major airports with significant other differences, the same sort of interviews with gate agents at five other airports took place. These airports were LAX, PIT, CLT, HOU, and MIA. The ramp procedures verbally reported and observed were essentially the same throughout the noted airports.

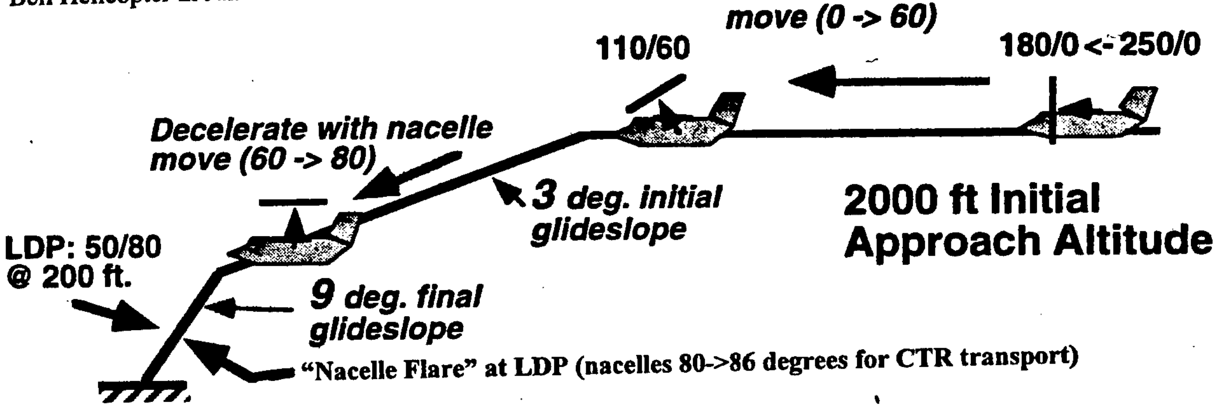
It is not likely that the amount of thrust (and accompanying downwash) needed to move a Tiltrotor is more than a helicopter of the same weight. The propwash and certainly the jet blasts from light to heavy turbojets are many times greater than the tiltrotor taxiing downwash velocities to be expected. Therefore, it is assumable that the same procedures in use for today's airport ramps are sufficient to safely deal with the same issues from Tiltrotors. Many years of experience with the larger Sikorsky's S-61, S-70, and CH-53 indicate the ramp and taxiing issues related to safety are not an issue that requires extraordinary procedures beyond that which is common aviation practices.

VERTIPORT DESIGN AC REVISION - WHITE PAPER
CTR STEEP APPROACH PROFILE FOR NOISE ABATEMENT

William A. Decker, NASA Ames

November 17, 1997

Nominal approach profiles for a CTR transport have been under development at NASA Ames Research Center for the past several years. Each successive profile development sought to achieve a workable compromise among flight safety (particularly single engine performance), pilot workload in an instrument flight environment, a desire for steep final approaches to minimize approach obstruction plane requirements, and flight condition (airspeed, nacelle position and descent angle or rate) control for noise abatement. The profile shown below represents the current development. This profile was modified from the previous CTR-6 simulation experiment profile based on pilot comment and incorporates lessons learned from extensive XV-15 terminal area operations noise measurement tests conducted by NASA and Bell Helicopter in June 1997.



Flight condition at Landing Decision Point:

50 Knots, 80 degrees Nacelle Angle

200 feet above landing surface on 9 degree glide slope.

With a Landing Commitment, decelerate to a hover (vertical touchdown) for landing, using a "Nacelle Flare":

Nacelles moved to hover position (86 degree for generic 40-passenger transport, 90 degree for XV-15) using discrete nacelle control. Minor pitch attitude adjustments as necessary.

Specific approach profile elements:

1. Initial approach altitude prior to conversion from airplane model should be no lower than 2000 feet AGL. This provides height for the pilot to react to loss of all engines, select a landing site, configure the aircraft (full aft nacelles--started moving around 800 feet AGL) and land. A tiltrotor landing with all engines failed is similar to a conventional fixed-wing dead-stick landing, but with nacelles moved to the full-aft position. The roll-on touch-down speed is around 50 knots. Remember that we are talking about a 40-passenger twin-engine transport, so this should be an extremely remote requirement. Try doing that in any fixed-wing transport!

2. The initial conversion is listed as moving nacelles from 0 degrees (airplane mode) to 60 degrees (tilt mode). A large transport is expected to begin that conversion at 180 knots. The XV-15 begins the same conversion from 150 knots. Nacelle movement is controlled with a pilot-initiated discrete nacelle system. The pilot activates a switch on the Thrust Control Level head. The nacelles are then moved at a specified (slow) rate to the 60 degree position. With the NASA-developed system, the pilot can override the semi-

An area of current development concerns the specific nacelle movement rates used at various nacelle angles. The concern is that even a slow, 2 degree/second, rate is still too fast for the aircraft to decelerate sufficiently fast to avoid high proprotor dynamic loads and noise (too fast for a given nacelle angle). The approach profile used during the CTR-6 experiment addressed this concern with an additional nacelle stop at 30 degrees. Practical flying experience with tiltrotors suggests, however, that the 30 degree nacelle position is an uncomfortable flight condition, one to be avoided for any prolonged period. A simple explanation of this can be seen simply by looking at the effect of thrust variations. With nacelles at 30 degrees, most of the reaction to a thrust variation is horizontal (87%), but the vertical still sees 50% of the effect of the thrust variation. Consequently, the pilot or the flight control system has difficulty sorting out what control to use for velocity control versus height control. Adding further to pilot discomfort is that at 30 degrees nacelle angle, the rotor trip path plane is approximately (or seemingly) even with the pilot's head--a decidedly uncomfortable and noisy condition. The current discrete nacelle schedule addresses this concern by slowing the nacelle rate through the 20 to 40 degree range, but keeps nacelles in motion.

3. An initial glide slope of 3 degrees is used. This permits descent in a fairly fast flight mode while maintaining a modest noise signature. If noise were of lower concern, a speed of 120 knots would be used. The slower speed provides more margin from the area of intense blade vortex interaction, albeit at the cost of a higher pitch attitude.

4. For initial approach altitudes above about 3000 feet AGL, much of the conversion and deceleration from airplane mode to the 60 degree nacelle tilt mode condition can be done on the 3 degree glide slope. Care must be exercised during such conversions, though, to avoid adding too many other piloting tasks such as a turn--particularly while the nacelles are in motion. Nacelle motion produces a pitch attitude reaction--even in a well augmented control system (its the fundamental aircraft physics). Still, elements of this initial conversion and deceleration can be successfully performed while descending and maintaining IFR tracking precision with tolerable pilot workload.

5. The aircraft must be decelerated to an appropriate airspeed prior to intercept of a steeper glide slope. This deceleration is again initiated by a nacelle move, from 60 to 80 degrees. The objective is to slow to an airspeed approximating that needed for the approach profile planning rule of thumb: "Descend at no more than 1000 feet/minute when below 1000 feet AGL." The current approach profile begins the 9 degree descent a little fast at 70 knots (1100 fpm), but fairly soon decelerates toward 50 knots. This strategy has been used successfully in CTR simulations and now in the XV-15. Indeed, the higher airspeed is desirable as a counter to winds and turbulence as well as overall approach time efficiency. Although noise measurements of stable flight conditions suggest higher noise for a 9 degree flight path angle at 70 knots (vs. 50 knots), data from the June 1997, XV-15 test suggest any noise increase due to airspeed (and the deceleration) is offset by the reduced time exposure of the faster approach.

6. The transition to the 9 degree final glide slope angle is currently set to occur by 800 feet AGL (actual break point is at 900 feet). CTR-6 pilot comments and performance pointed to a need for a bit more space/time to settle on the new glide slope. Further, the higher (CTR-6 had used a 500 feet AGL transition point) break point is expected to provide a better obstruction clearance plane. Countering this is the need to slow down on the steeper glide slope, subjecting the aircraft to magnified (by low speed) effects of winds and turbulence. Tail winds will be a particular concern.

7. A nine degree final glide slope is used. While a steeper angle might provide better obstruction clearance and may even reduce the size of the noise footprint, the slower speeds and greatly reduced field of view relative to the flight path angle preclude final approach angles much steeper than nine degrees.

8. The landing decision point flight condition is set at 50 knots, 80 degrees nacelle, at 200 feet AGL. For the generic CTR transport, this flight condition provides for safe, single-engine go around at the decision point. Critical to the success of this strategy is the discrete nacelle control system, which provides repeatable, predictable aircraft response to nacelle movement at a critical flight point. Essentially, the pilot performs the landing flare (arrests forward speed and sink rate) using proprotor angle control, not body

attitude. By keeping the aircraft body relatively level, the pilot maintains a better field of view for the landing. For the XV-15, a similar strategy has been employed, moving nacelles from 85 to 90 degrees (the hover position for the XV-15).

Another important element for the CTR transport is an automatic flap schedule that deflects the flaps from 40 degrees at modest speed and 80 degrees nacelle (the high lift, medium drag flap position) to the fully deflected position (60+degrees). This both increases the drag and reduces the wing download for hover. When this landing strategy was first developed, flap settings above 40 degrees provided too much drag to assure a single engine go-around at the landing decision point. The nacelle angle-driven flap position provides a repeatable aircraft response using a reliable drive signal (nacelle angle versus airspeed--a poor signal at slow speeds).

Although the specific details of this approach profile have been refined through multiple simulation exercises and more recent XV-15 flight test, the basic elements of performing most of the conversion from airplane mode in level flight or shallow descent, followed by a steep final approach and a landing performed using a "nacelle flare" remain. The landing performed with the aid of a nacelle move represents a higher workload final approach than pilots might prefer. It deliberately trades off a slightly higher pilot workload for increased single engine safety speeds while addressing a desire for a steep final approach for obstruction clearance and noise abatement.

VERTIPORT DESIGN AC REVISION - WHITE PAPER
VERTIPORT STANDARD MARKING SYMBOLS

Robert D. Smith, FAA AND-710

July 22, 1997

Background - The Standard Vertiport Marking Symbol, A Very Abbreviated History

In the mid-1960's, the FAA sponsored a study of heliport marking symbols. This effort was conducted by the Army Corps of Engineers with significant rotorcraft industry involvement. The objective of this study was to determine the marking pattern that would best fulfill requirements established on the basis of then current practices, discussions with helicopter pilots, and objective testing. The requirements and advantages of a heliport marking pattern included such issues as the following:

a. identification of a heliport site from a minimum distance of one mile (1.6 km), measured on the ground, at viewing angles from 5 to 20 degrees inclusive under VFR conditions.

b. directional control to the pilot during the approach to the helipad.

c. a field of reference to assist the pilot in maintaining the correct attitude of the helicopter during the approach to the helipad.

d. assistance to the pilot in controlling the rate of closure to the helipad.

e. a point of convergence to the desired touchdown or hover area.

f. assistance to the pilot in determining the location of the helicopter with respect to the touchdown or hover point when the helicopter is directly over the helipad.

Among the conclusions of the laboratory portion of the 1960's testing were the following:

1. A minimum pattern size of 75 feet is needed to be identifiable from a distance of one mile.

2. Pattern identification works best when the pattern is between 50 and 83 percent of the size of the helipad. (Smaller patterns tend to disappear. Larger patterns tend to blend with the edge markings.)

During laboratory testing, 25 candidate marking symbols were evaluated. Seven were selected for flight testing. Based on flight tests, "Pattern F" (Maltese Cross) "was the first choice by a great majority". "Pattern B" ("broken-wheel") was a respectable second choice. The remaining patterns trailed far behind. Thus, the Maltese Cross was selected as the standard heliport marking pattern. In the late 1970's, however, the FAA Administrator repealed this standard when it was charged that the Maltese Cross was anti-semitic. At this point, it would have been logical to adopted "Pattern B" ("broken-wheel") as the standard marking. Apparently, however, this was not considered. In the 1977 Heliport Design Guide AC, the "triangle H" was recommended as the standard heliport marking symbol even though prior testing had shown that it had serious shortcomings. By the time the 1988 Heliport Design AC was published, the shortcomings of the "triangle H" had been widely recognized and the large "H" became the recommended marking for public heliports. (The large "H" had not been one of the symbols tested in the mid-1960's.)

In the late 1980's, the FAA developed a Vertiport Design Advisory Circular. Part of this effort addressed the issue of a vertiport marking symbol. Initially, "VTOL" was selected as the standard vertiport symbol. However, during flight testing, both FAA and industry pilots concluded that this pattern did not work very well. In reconsidering this issue, the FAA revisited the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern. The FAA asked the members of the Vertiport Design Working Group (WG) to consider the requirements listed above (a through f). WG members confirmed that the list of

desirable characteristics for a heliport marking symbol were also appropriate for a vertiport marking symbol. The WG members concluded that this list should be retained with no additions or deletions. Subsequently, they recommended that the FAA adopt "Pattern B" (broken-wheel) as the standard vertiport marking symbol. Regretfully, the FAA also adopted industry's recommendation that the minimum height of this symbol should be a mere 28 feet rather than the 75 feet recommended by the 1967 study.

Background - NASA Simulation Testing of Vertiport Approaches

NASA tiltrotor simulation efforts have involved the simulation of vertiports including markings consistent with the Vertiport Design AC. Mr. William Decker briefed the Vertiport Design WG on simulation results at the April 22, 1997 WG meeting. In the initial simulation flights, NASA used the standard vertiport marking symbol with a 28 foot minimum height as recommended by the current Vertiport Design AC. One pilot commented that the 28 foot symbol was almost invisible. Another pilot commented that it looked like an "X", the indication of a closed facility. Clearly, the 28 foot height was grossly inadequate. Based on these subject pilot inputs, NASA quickly modified their simulation by increasing the size of the standard vertiport marking symbol to 100 feet. Pilots found this to be adequate.

For an extended TLOF, NASA has also recommended that the vertiport marking symbol should be placed in the middle of the TLOF as an aiming point rather than putting one symbol on each end of the extended FATO as currently recommended by the Vertiport Design AC. NASA argues that centering the symbol in the middle of an extended TLOF supports approaches to that central point. "Center approaches" provide for "under-run" for both one-engine-out (OEI) recovery and for the normal flight dispersion (flight technical error) associated with an approach. NASA has routinely observed tiltrotor pilots, both in the simulator and in flight, dropping under the prescribed approach path in the final stages of approach. NASA believes that the reasons for this are at least two-fold:

1. Pilots state that they want to SEE the aim point (steep approaches make this more difficult).

2. As rotorcraft decelerate to a hover, the physics of flight require increased power, the primary height control at low speed. Pilots usually lag the visual alignment cues. Thus, they drop below the straight-in flight path.

Thinking of a comparable situation with a conventional runway approach, NASA points out that the runway aiming point is displaced 1000 feet from the threshold (see figures 1 and 2 from AC150/5340-1G, Standards for Airport Markings, shown later in this white paper). Thus, conventional runway markings are similar to what NASA is proposing for a vertiport with an extended TLOF markings. Putting the vertiport marking in the center of an extended TLOF would provide the pilot with a better view of the aiming point. It would also provide a safety margin for addressing the normal approach dispersion.

Discussion - Size of the Vertiport Marking Symbol

At their April 22, 1997 meeting, the Vertiport Design Working Group recommended that the vertiport marking symbol be two thirds of the FATO width with a minimum dimension to be decided after further deliberations on the issue of FATO width. This recommendation was based on the results of the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern and on the NASA simulation testing shown above. The 1967 study recommended a minimum height of 75 feet.

The current Vertiport Design AC recommends that the width of the FATO be at least 100 feet for a VFR facility and 150 feet for a IFR facility (see par. 12a). Thus, for a VFR vertiport, a 75 foot minimum height is appropriate for the vertiport marking symbol. And, for an IFR vertiport, a 100 foot minimum height is appropriate for the vertiport marking symbol. In flying IFR approaches in a NASA tiltrotor simulator, the subject pilots found a 100 foot high marking symbol to be adequate.

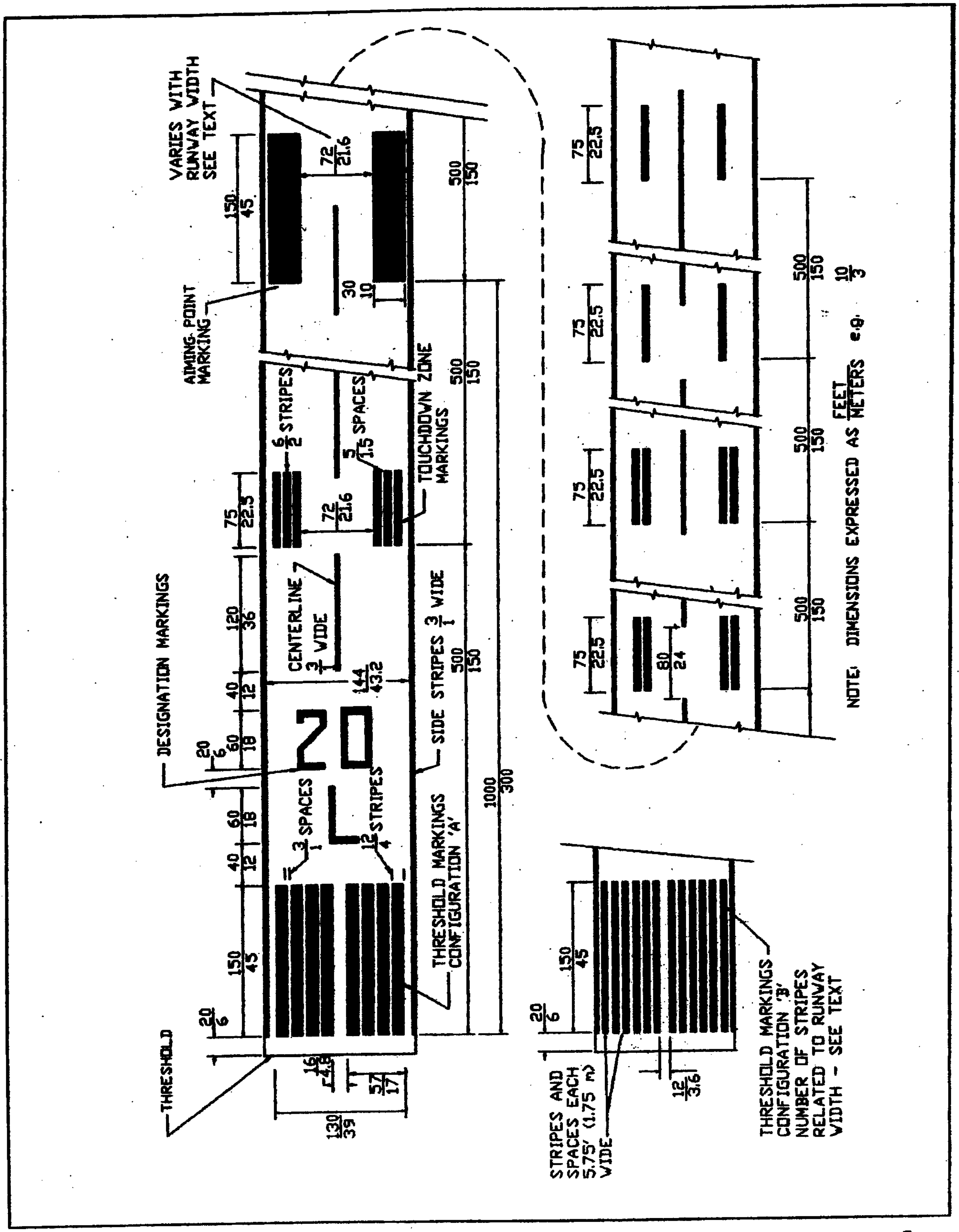


Figure 1. Precision Instrument Runway Markings

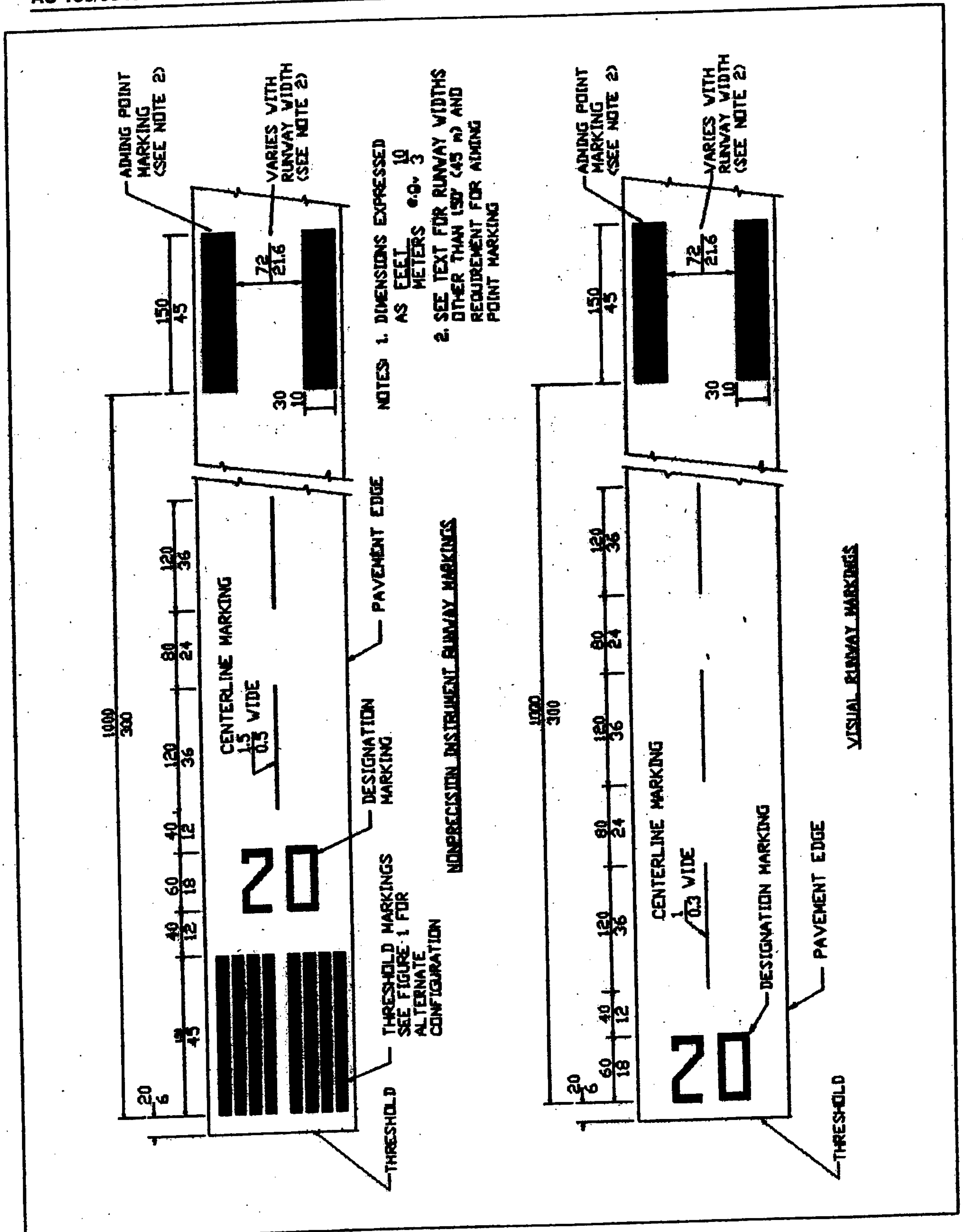


Figure 2. Nonprecision Instrument Runway and Visual Runway Markings

Discussion - Location of the Vertiport Marking Symbol

For an extended TLOF, NASA has also recommended that the vertiport marking symbol should be placed in the middle of the TLOF as an aiming point rather than putting one symbol on each end of the extended FATO as currently recommended by the Vertiport Design AC. This would provide the pilot with a better view of the aiming point. It would also provide a safety margin for addressing the normal approach dispersion. Thus, moving the vertiport symbol to the centers of the extended TLOF could be expected to increase the safety of tiltrotor operations and probably helicopter operations as well.

One of the safety benefits, of having the vertiport marking symbol at each end of an extended TLOF, is that it would give the fixed-wing pilot one last chance to do a missed approach and land somewhere else. As seen in figures 1 and 2, both precision and nonprecision instrument runways have threshold markings that make the runway look much different than an extended TLOF. However, a visual (non-instrument) runway (see figure 2) does not have such markings. Thus, the end of a visual runway does not look dramatically different from the end of an extended TLOF if the standard marking symbol has been moved from the TLOF end to the center. If this done, is the fixed-wing pilot more likely to mistake a TLOF for a runway? Is there another indicator that would provide the fixed-wing pilot with the same forceful prominent alert as the use of the vertiport marking symbol on the runway ends? Could this indicator be used without encouraging an undesirable reaction by tiltrotor or helicopter pilots? Is the risk sufficient to justify the use of some other marking on the runway ends? In answering this last question, consider this thought. The likelihood of a fixed-wing landing at a vertiport is small, but an aviation accident is also a rare event. If aviation accidents are to become increasingly rare, the aviation community must plan and design to avoid even unlikely events.

Summary

Simulation testing has shown that the 28 foot minimum height for the vertiport marking symbol (broken wheel) is grossly inadequate. This should come as no surprise to anyone familiar with the results of the 1967 study of heliport marking patterns. The 1967 study recommended a minimum pattern size of 75 feet. However, it also recommended that the pattern be between 50 and 83 percent of the size of the helipad. At a vertiport with an extended TLOF, this recommendation would mean that the vertiport marking symbol should be between 50 and 83 percent of the width of the TLOF. Thus, for a VFR vertiport, a 75 foot minimum height is appropriate for the vertiport marking symbol. And, for an IFR vertiport, a 100 foot minimum height is appropriate for the vertiport marking symbol.

Placing the vertiport marking symbol in the middle of the TLOF as an aiming point would provide the pilot with a better view of the aiming point. It would also provide a safety margin for addressing the normal approach dispersion. Thus, moving the vertiport symbol from the ends of the TLOF could be expected to increase the safety of tiltrotor operations and probably helicopter operations as well.

One of the benefits of having the vertiport marking symbol at each end of an extended TLOF is that it would give the fixed-wing pilot one last chance to do a missed approach and land somewhere else. If the standard marking symbol is moved to the center of the extended TLOF, should some other symbol be placed on the ends of an extended TLOF to provide the fixed-wing pilot with the same forcefully warning?

References

AC 150/5390-3 May 31, 1991	**Vertiport Design**
TR 4-67 Sept. 1967	**Development Study for a Helipad Standard Marking Pattern** (NTIS AD-660359)
AC 150/5340-1G Sept. 27, 1993	**Standards for Airport Marking**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
VERTIPORT TLOF AZIMUTH DESIGNATIONS

Robert D. Smith, FAA AND-710

July 22, 1997

Background

AC150/5390-3, Vertiport Design, shows several illustrations of vertiport TLOF azimuth markings. Figure 4-1, Typical Vertiport Marking and Lighting, is a notable example (shown later in this white paper). However, the advisory circular (AC), says little about the dimensions and the exact placement of these azimuth markings. The following is an excerpt from paragraph 41b(1):

> "The distinctive marking shown in this AC is recommended for identifying a vertiport. Dimensions for the marking, suitable for a 100 foot (30 m) wide TLOF, are found in Appendix 2. The marking is centered on a square TLOF and is 20 feet (6 m) in from the end of an elongated TLOF. A one or two digit number, at least one-half the size of the symbol, reflecting the nearest 10 degrees of magnetic heading of the approach, identifies the ends of an elongated TLOF."

In Appendix 2, AC150/5390-3 recommends a minimum height of 28 feet for the standard vertiport marking symbol. Thus, the current Vertiport Design AC recommends that the TLOF azimuth heading be at least 14 feet high. AC150/5390-3 does not address the ratio of the height and width of this symbol. It also neglects to specify the exact location (distance from the end of the TLOF).

AC150/5340-1G, Standards for Airport Markings, does specify the size and proportion of the azimuth marking in paragraph 6, Runway Designation Marking, subparagraph 6d(2) and figure 4 (shown later in this white paper). This AC recommends that all of the numbers, except the 6 and the 9, be 60 feet tall. A height of 63 feet is recommended for the 6 and the 9. For seven of the ten numbers, a width of 20 feet is recommended. A width of 23 feet is recommended for the 7 and 25 feet for the 4. For the 1, a width of 7 feet is recommended when the number is used in conjunction with another digit. When a 1 is used alone, the AC recommends the addition of a horizontal bar at the bottom to distinguish it from the runway centerline. When this bar is added, the recommended width of the number 1 is 20 feet. Thus, runway designation numerals are roughly 60 feet high and 20 feet wide.

NASA tiltrotor simulation efforts have involved the simulation of vertiports including markings consistent with the Vertiport Design AC. Mr. William Decker of NASA Ames briefed the Vertiport Design Working Group (WG) on simulation results at the April 22, 1997 meeting. Simulator pilots (industry, NASA, and FAA) have found the current minimum height of the standard vertiport marking symbol (28 feet) to be inadequate. One pilot commented that the 28 foot symbol was almost invisible. Another pilot commented that it looked like an "X", the indication of a closed facility. Based on these subject pilot inputs, NASA quickly modified their simulation by increasing the size of the standard vertiport marking symbol to 100 feet. Pilots found this to be adequate.

If the simulation pilots found the 28 foot vertiport marking symbol to be inadequate, one can imagine what they would have said about a 14 foot vertiport azimuth marking. However, in this simulation effort, NASA used TLOF azimuth markings consistent with the size and proportions recommended in AC150/5340-1G (60 feet tall). The question now at hand: "Is the guidance developed for 3 degree runway approaches also optimal for approaches to vertiports or is some alteration appropriate?"

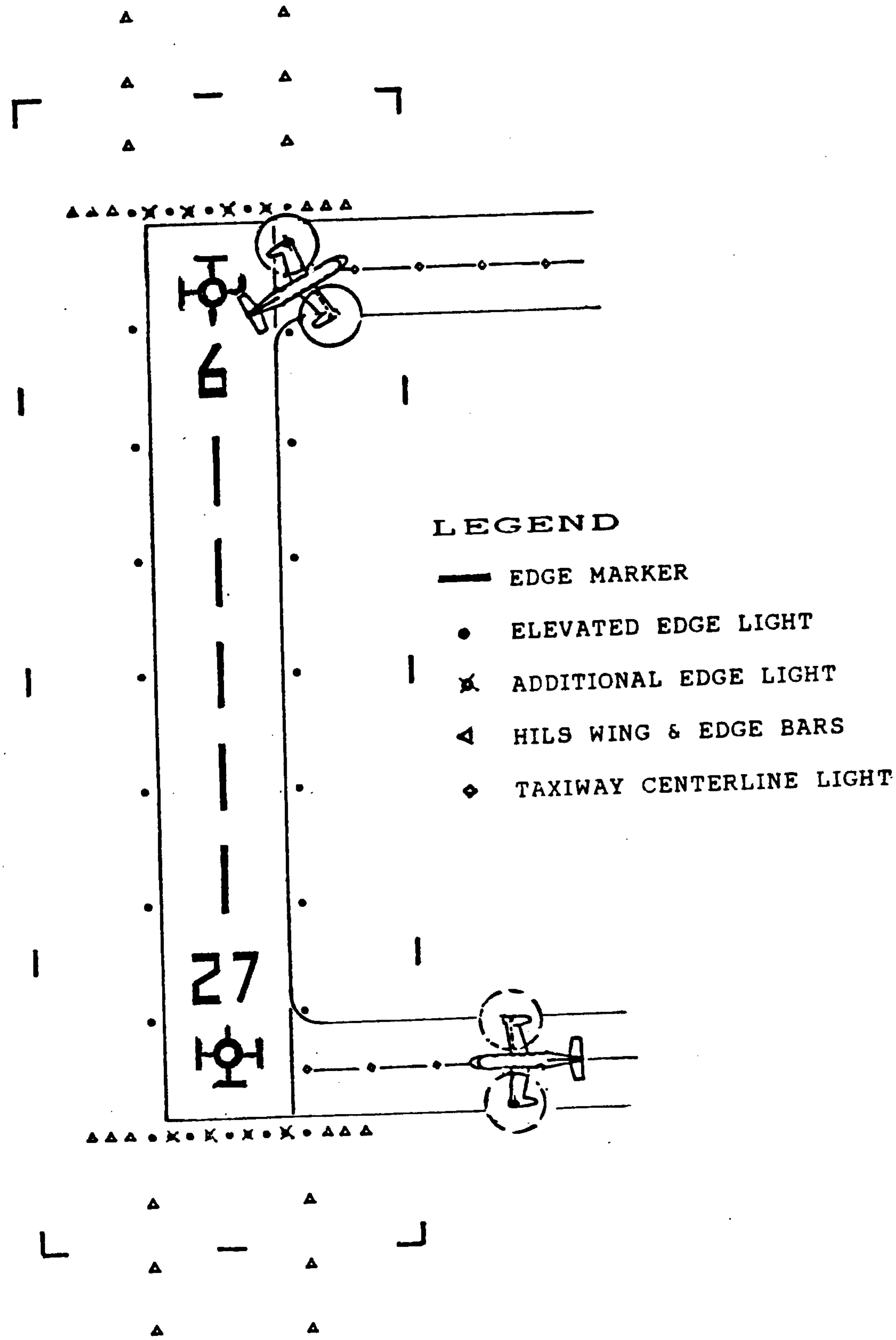
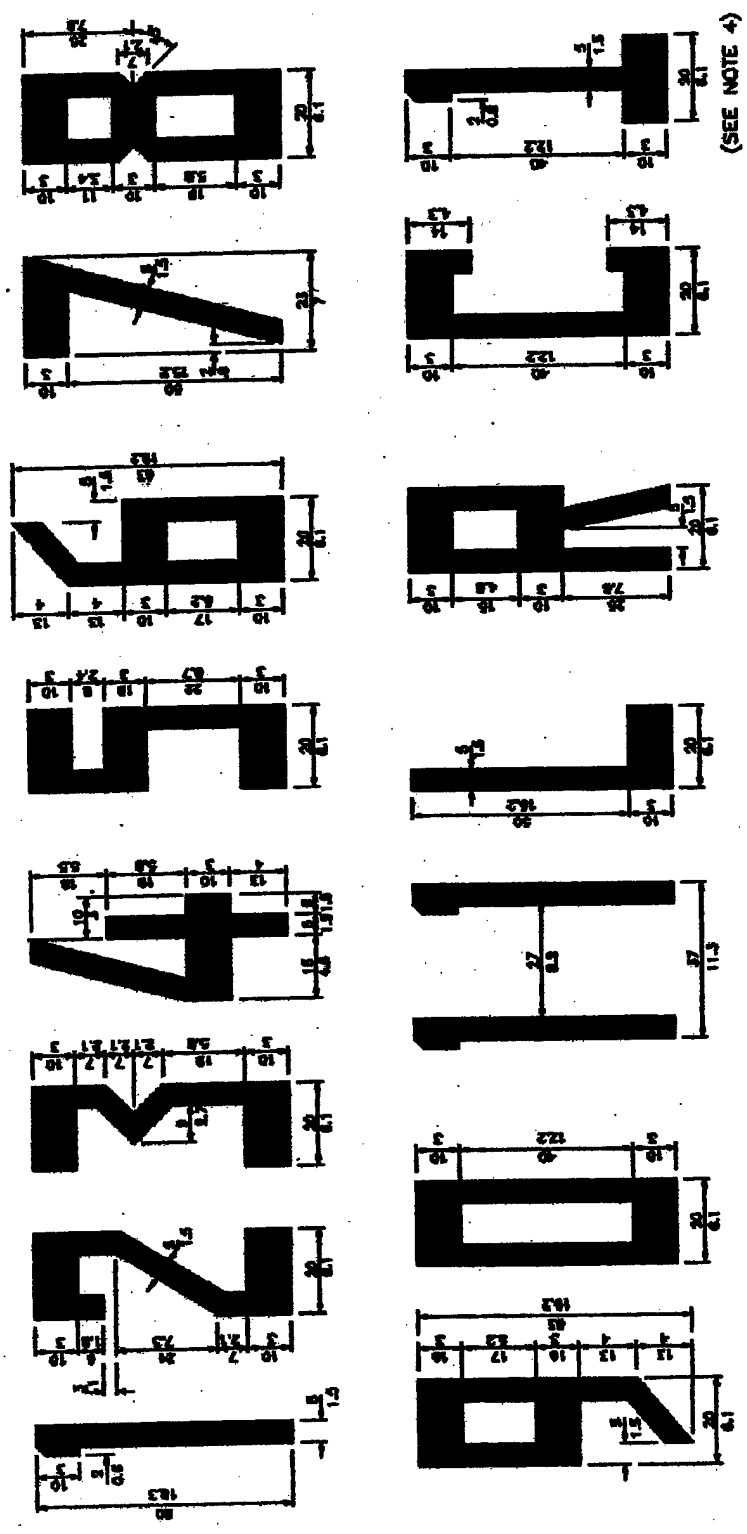


Figure 4-1. Typical vertiport marking and lighting



NOTES:

1. ALL NUMERALS EXCEPT THE NUMBER ELEVEN AS SHOWN ARE HORIZONTALLY SPACED 15 FEET (4.6 METERS) APART
2. SINGLE DIGITS SHALL NOT BE PRECEDED BY A ZERO.
3. DIMENSIONS ARE EXPRESSED THUS: $\frac{\text{FEET}}{\text{METERS}}$ e.g. $\frac{30}{9}$
4. THE NUMERAL 1, WHEN USED ALONE, CONTAINS A HORIZONTAL BAR TO DIFFERENTIATE IT FROM THE RUNWAY CENTERLINE MARKING
5. SINGLE DESIGNATIONS ARE CENTERED ON THE RUNWAY PAVEMENT CENTERLINE. FOR DOUBLE DESIGNATIONS, THE CENTER OF THE OUTER EDGES OF THE TWO NUMERALS IS CENTERED ON THE RUNWAY PAVEMENT CENTERLINE.
6. WHERE THE RUNWAY DESIGNATION CONSISTS OF A NUMBER AND A LETTER, THE NUMBER AND LETTER ARE LOCATED ON THE RUNWAY CENTERLINE IN A STACKED ARRANGEMENT AS SHOWN IN FIGURE 1.

Figure 4. Runway Designation Numerals and Letters

Discussion - The Purpose of Runway Designation Numbers

The purpose of the runway designation number is to provide an simple, unambiguous way to designate a specific runway end. This allows the pilot to discuss the matter with air traffic control should that be appropriate for a given airport. A runway designation also provides the pilot with a safety check in determining whether he is approaching the correct runway end. The runway designation is not the sole check available to the pilot for this purpose but it is a very useful check none the less. Pilots can also determine if they are approaching the correct runway via such checks as runway heading, airport layout, etc. Yet landing on the wrong runway is a problem reflected in general aviation accident and incident reports. On very rare occasions, one even hears of airline pilots landing at the wrong airport. Thus, it is clear that runway designations can be very useful safety device even if they are sometimes overlooked.

Discussion - Size and Proportion of the TLOF Azimuth Designations

With typeface numbers, the typical height-to-width ratio is slightly less than 2:1. With runway designation numerals, the height/width ratio has been increased to 3:1 in order to compensate for a viewing angle that is typically much less than 90 degrees. On a long straight-in precision approach with no downwind leg, a limited survey of pilots indicates that the runway designations can be reliably read at a distance of one mile in clear weather during daylight hours. When viewed during a 3 degree precision approach, a 60 foot high number appears to be less than 4 foot tall. As an approximation of this, look at figure 4 from AC150/5340-1G and tip the paper until the height appears to be one fifth of the width.

Consider now a 9 degree approach to a vertiport. When viewed during a 9 degree precision approach, a 60 foot high number appears to be less than 10 foot tall. The higher approach angle makes it easier to read the azimuth designation. Thus, it does not appear to be appropriate to change the height-to-width ratio of these numbers when they are used on an extended TLOF at a vertiport. Clearly, however, the 60 foot height should also be retained.

Summary

On a 9 degree approach, the standard runway designations can be reliably read at a distance of one mile in clear weather during daylight hours. These designations are easier to read on a 9 degree approach than on a 3 degree approach. Thus, it does not appear to be appropriate to change the height-to-width ratio of these numbers when they are used on an extended TLOF at a vertiport. Clearly, however, the 60 foot height should also be retained.

References

AC150/5340-1G Sept. 27, 1993	**Standards for Airport Markings**
AC 150/5390-3 May 31, 1991	**Vertiport Design**
TR 4-67 Sept. 1967	**Development Study for a Helipad Standard Marking Pattern** (NTIS AD-660359)

VERTIPORT DESIGN AC REVISION - WHITE PAPER
SAFETY

Robert D. Smith, FAA AND-710

April 22, 1997

Background

In November 1996, Bell and Boeing publicly announced that they had committed to producing the first civil tiltrotor (CTR). The Bell/Boeing 609 (previously called the D-600) will be a two-engine, 16,000 pound aircraft with a maximum cruise speed of 275 knots, a maximum range of 750 nmi, and a 25,000 ft operational ceiling. With 1-2 pilot(s), it will carry 6-9 passengers depending on configuration.

The first flight of the BB-609 is planned for July 1999, civil certification is planned for December 2000, and first delivery in early 2001. The purchase price is $8-10M depending on how it is equipped.

Discussion

Looking downstream about 15 years, there are many who expect to see at least three or four models of CTR flying in sizable numbers. Of these, the BB-609 is likely to be the easiest CTR model to introduce. By contrast, the CTR2000 is expected to be the most challenging to introduce. Issues of particular concern include noise, community acceptance, availability of landing sites in close proximity to demand centers, and passenger acceptance.

Safety is an issue that can not be overlooked. As the BB-609 is introduced, it will start to develop an operational history. Aviation accidents are rare events. Still, people and machines are not perfect and CTR accidents will eventually occur. As CTR operational history develops, people will be able to compare its accident rate with other segments of the aviation industry. Taken as a group, the major airlines consistently have the best aviation accident rate and this constitutes the bench mark against which all other aviation activities are compared.

When the manufacturers are ready to make the billion-dollar-plus decision on whether to produce the CTR2000, the accident rate of previous CTR aircraft is likely to be a significant consideration. If the CTR accident rate compares well with the major airlines, this will be a significant point in favor of the introduction of the CTR2000. If the CTR accident rate does not compare well with the major airlines, passenger acceptance could be expected to be low. This would make it considerably more difficult for the manufacturers to make a production commitment on the CTR2000.

Summary

The introduction of the BB-609 provides the tiltrotor community with an opportunity to demonstrate whether the CTR is a safe aircraft. If the CTR accident rate compares well with the major airlines, this will be a significant point in favor of the introduction of the CTR2000. If the CTR accident rate does not compare well with the major airlines, it would be difficult or impossible to make a positive decision on the production of an aircraft such as the CTR2000. Thus, in introducing the BB-609, it is doubly important to do so in a way that will result in a very low accident rate.

Reference

No Report Number December 1995	**Civil Tiltrotor Development Advisory Committee - Report to Congress**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
VERTIPORT CAPACITY

Robert D. Smith, FAA AND-710

April 22, 1997

Background

The Civil Tiltrotor Development Advisory Committee (CTRDAC) concluded that a 40- passenger CTR would be technically and economically feasible. CTR could produce significant societal benefits including reduction of delays at congested airports, increased aviation capacity, and increased transportation options. CTRDAC market analysis indicates that there are numerous markets where properly located vertiports would quickly grow to annual enplanements of several hundred thousand or more. Thus, in developing the design requirements to satisfy this operational need, we must recognize that this is a small airport rather than a large heliport. In transitioning from heliports to commercial vertiports, a paradigm shift is required. Vertiport capacity requirements will affect many commercial vertiport design parameters.

Discussion

If we wanted to build a vertiport in Manhattan to handle 500,000 annual enplanements, how many gates would be required, how many parking spots (passengers and employees), how many FATO's, how large should the lobby/waiting area be? How should the FATO(s)/taxiway/gates be configured to maximize capacity? How much "airline space" is required for ticket counters, offices, baggage, etc.? What are the requirements for access roads, taxicab waiting space, and rental car operations?

On capacity issues, the only guidance provided by the Vertiport Design AC is a reference to AC 150/5360-9, Planning and design of Airport Terminal Facilities at Non-Hub Locations. This 1980 AC offers guidance on requirements for parking spots, lobby/waiting areas, "airline space", and a few other capacity topics. Does the guidance of AC 150/5360-9 represent the aviation community's best thinking? Based on limited discussions with airport designers, opinions on this question are both positive and negative. Is any of AC 150/5360-9 applicable to vertiports? Opinions on this question also appear mixed but more negative than positive. Should AC 150/5360-9 continue to be referenced in the Vertiport Design AC or should separate material be developed for inclusion in AC150/5360-3? Opinions here appear to favor deleting the reference to AC150/5360-9 and developing material specifically directed toward vertiport terminal facilities.

It should be noted that AC 150/5390-9 provides no guidance on the number of gates required to handle an expected number of annual enplanements. No current AC provides specific guidance on how vertiport FATO(s), taxiways, and gates should be configured to maximize capacity. What current design guidance is available on the relationship between airport layout and capacity? Would any of this material provide a foundation for the development of similar guidance for vertiports?

CTRDAC discussions raise questions about the difference between airport and vertiport requirements on issues such as baggage and passenger parking requirements. Some CTRDAC members questioned whether CTR passengers will carry as much luggage as airline passenger. Is this a reasonable assumption? Is there some portion of the air commuter industry whose passenger profile is similar to what can be expected for the 40-passenger CTR? Some in industry have suggested that the NYC/Boston air commuter market would have the appropriate passenger profile. Is this segment of the industry likely to provide an acceptable estimate of baggage requirements for passengers of the 40-passenger CTR? How would we estimate baggage system space requirements? (While baggage may seem a mundane issue, the Denver Airport certainly provides an example of how problems with a baggage system can have large repercussions.) Would this segment of the commuter provide an acceptable estimate of parking requirements at vertiports?

CTRDAC discussions also addressed the possibility that vertiport parking requirements for a downtown location would be different from those of a suburban vertiport with the same annual enplanements. Is this a reasonable assumption? How can we estimate passenger parking requirements as a function of annual enplanements and other applicable variables?

Summary

For the 40-passenger CTR, what capacity issues need to be addressed by the Vertiport Design AC? For the 9-passenger CTR, what capacity issues need to be addressed by the Vertiport Design AC? Which capacity issues should be addressed in the text of the Vertiport Design AC and which should be addressed by reference to other documents? Is there sufficient information available to develop all the guidance material needed on capacity issues? Are there areas where additional research is needed? Are there areas where final judgments can only be made after we acquire operational experience with the aircraft? In those areas, what guidance can we provide in the absence of operational experience?

On capacity issues, the only guidance provided by the Vertiport Design AC is a reference to AC 150/5360-9, Planning and Design of Airport Terminal Facilities at Non-Hub Locations. Based on limited discussions with airport planners, this 1980 AC does NOT represent the aviation community's best thinking. Thus, it appears appropriate to delete the reference to AC150/5360-9 and to develop material specifically addressing vertiport terminal facilities. Are we prepared to develop such material?

Reference

No Report Number December 1995	**Civil Tiltrotor Development Advisory Committee - Report to Congress**
FAA/ND-95/3	**Vertiport Capacity - Analysis Methods**
AC 150/5360-3 April 1980	**Planning and Design of Airport Terminal Building Facilities at Nonhub Locations**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
VERTIPORT TERMINAL GATE SEPARATIONS

Robert D. Smith, FAA AND-710

April 22, 1997

Background

The Civil Tiltrotor Development Advisory Committee (CTRDAC) envisioned vertiports whose annual enplanements will be several hundred thousand or more. Thus, in developing the design requirements to satisfy this operational need, we must recognize that a commercial vertiport will be more like a small airport than a large heliport. Preliminary capacity indicates the need for multiple gates at a vertiport. Intuitively this makes sense. Consider the typical commercial airport with several hundred thousand enplanements. How many gates does it have?

In the absence of operational experience with a large CTR, there is much that is uncertain. Of particular interest are the parameters of gate utilization and gate occupancy time. To deal with these and other variables, preliminary analysis has resulted in a matrix of estimated gate requirements based on different assumptions. To handle 10 CTR arrivals per hour, analysis estimate that between 2 and 14 gates will be required. To handle 30 CTR arrivals per hour, analysis estimates that between 7 and 36 gates will be required (see page 39 of FAA/ND-95/3). The broad range of values is indicative of our current lack of knowledge on exactly how the CTR will function as a transport aircraft. However, it is clear the number of gates required could be large. Thus, the minimum separation required between these gates will have a significant effect on the overall size of the vertiport.

Discussion

Vertiport capacity will be significantly reduced if CTR can not operate independently at adjacent gates. One way to enable independent operation is through the use of "jetways" or some similar structure. Such facilities could shield passengers from the rotorwash of a nearby CTR (and inclement weather) during loading and unloading. In the absence of "jetways", two choices are available. One possibility is to design the vertiport with large separations between gates to allow passenger loading/unloading independent of CTR operations at adjacent gates. A second possibility is to accept that operations at adjacent gates will not be independent along with the associated significant decrease in gate capacity. At vertiports where both capacity and land cost are important issues, the use of jetways or "loading bridges" may be the most cost effective solution. Vertiport configuration can also have a significant effect on the interdependence of operations at different gates.

During CTRDAC deliberations, one committee member stated his expectation that, with the 40-passenger CTR, engines would not shutdown and that rotors would continue to turn during loading and unloading operations. Among the reasons that would support this position are the following. First, this would keep gate occupancy time to a minimum during peak hour operations. Second, this would help to minimize CTR travel time and make it more competitive with other modes of transportation. Third, this would help to maximize the life of the engines. Are these reasonable arguments? Gate separation design requirements will vary based on what assumption is made on this issue.

At the November 25 Vertiport Design WG meeting, the WG concluded that, with the 40- passenger CTR, engines WOULD shutdown and that rotors WOULD NOT continue to turn during loading and unloading operations. This is a decision that has a significant impact on vertiport design. Since there are no operators of the 40-passenger CTR represented on the WG, are we confident that we can provide an authoritative answer to this question?

During taxi operations, CTR rotorwash will differ depending on whether such maneuvers are ground taxi, hover taxi, or air taxi operations. It appears likely that the 40-passenger CTR will ground taxi most of the time. Is it reasonable to assume that they will ground taxi ALL of the time? With the 9-passenger and other sizes of CTR aircraft, will ground maneuvers be ground taxi, hover taxi, air taxi, or all three? Another

consideration involves the means that will enable the 40-passenger CTR to push back from a gate on departure. Will this be done using a negative CTR nacelle angle or will a tug be used?

At the November 25 Vertiport Design WG meeting, the WG concluded that, with the 40- passenger CTR, the rotorwash generated by the hover-taxi or air-taxi would be so severe that it could not be allowed to occur. The Vertiport Design AC is not that appropriate document to prohibit such operations. The AC could state specifically that the vertiport design parameters have been developed with the understanding that hover-taxi or air-taxi would not take place. Would this be adequate to ensure safety of operations or should some additional action be taken via some other means? If so, what means would be appropriate?

For 40-passenger CTR commuter service, an argument could be made that jetways/loading bridges will be required in order to provide service comparable to what is now provided by the airlines (see a separate issue paper on this topic). Should this be a minimum design requirement or should this be an option to be decided case by case? At vertiports where there will be NO 40-passenger CTR operations, is it reasonable to expect that the facility would not include jetways/loading bridges?

Should we assume that loading bridges will not be a minimum requirement? If this is done even for the 40-passenger CTR, then it appears that vertiport gate separation requirements should be developed for each of the following scenarios:

a. <u>Gate separation requirements when operations at adjacent gates are unconstrained and enclosed jetways/loading bridges are not used</u>. This application would be appropriate when vertiport capacity is critical but land cost/availability is not critical. Large separations between gates will be required in order to protect passengers from rotorwash during loading and unloading at one gate while a second CTR is entering or departing an adjacent gate or sitting with rotors turning.

b. <u>Gate separation requirements when operations are somewhat constrained and enclosed jetways/loading bridges are not used</u>. "Operations are somewhat constrained" means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. However, the CTR at the adjacent gate may have rotor's turning. This application would be appropriate when vertiport capacity is not a critical issue. (This case could be ignored if we are certain that rotors will NOT continue turning while at the gate.)

c. <u>Gate separation requirements when operations are constrained and enclosed jetways/loading bridges are not used</u>. ("Operations are constrained" means that loading and unloading at one gate would not occur while a second CTR is entering or departing an adjacent gate. In addition, the CTR at the adjacent gate will NOT have rotor's turning.) This application would be appropriate when vertiport capacity is not a critical issue but land cost/availability is critical.

d. <u>Gate separation when enclosed jetways/loading bridges are used</u>. This application would be appropriate when vertiport capacity and land cost/availability are both critical issues. Gates separation requirements will be small and independent operations at adjacent gates will be possible but enclosed loading bridges will be required to accomplish this. "Independent operations" means that loading and unloading at one gate can occur while a second CTR is entering or departing an adjacent gate.

e. <u>Other scenarios</u>? Are there other scenarios that should be considered?

For the 9-passenger CTR operating at a non-commercial vertiport, what assumptions should be made about aircraft operations when the facility has more than one "gate"?

Summary

For the 40-passenger CTR, the minimum separation required between vertiport gates will have a significant effect on the overall size of the facility. At many vertiport sites, the cost of land or its lack of availability may dictate the use of passenger loading bridges. Where land cost and availability are not major issues, other design possibilities may be practical. Still to be resolved are questions whether other factors will cause loading bridges to be considered a minimum requirement for CTR commuter operations rather than an option. These factors include issues of passenger comfort and laws concerning the loading and unloading of handicapped passengers (see other issue papers).

References

No Report Number December 1995	**Civil Tiltrotor Development Advisory Committee - Report to Congress**
FAA/ND-95/3	**Vertiport Capacity - Analysis Methods**
FAA/RD-94/10	**Vertiport Characteristics**
FAA/RD-93/17	**Safe Heliports Through Design and Planning - A Summary of FAA Research and Development**
FAA/RD-93/31,I	**Rotorwash Analysis Handbook: Volume I - Development and Analysis**
FAA/RD-93/31,II	**Rotorwash Analysis Handbook: Volume II - Appendixes**
FAA/RD-90/17	**Analysis of Rotorwash Effects in Helicopter Mishaps**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
PASSENGER LOADING BRIDGES AND PASSENGER COMFORT

Robert D. Smith, FAA, AND-710

April 22, 1997

Background

American Eagle has a $12 million hub renovation project underway on Concourse G at Chicago O'Hare. They are adding four new gates and a 6,800 square-foot waiting lounge on the lower level bringing their total lounge area to approximately 33,000 square-feet. This effort includes the installation of 20 passenger loading bridges designed and built by Jetway Systems of Ogden UT. These bridges are similar to jetways used at major airports but the design has been modified to accommodate the passenger loading and unloading of turboprop aircraft. American Eagle claims that this renovation will turn O'Hare Concourse G into "the first regional hub facility in the world to offer covered boarding on such a large scale." In addition to O'Hare, this loading concept will be introduced in 15 other midwestern and southwestern cities during 1997 and 1998.

Discussion

Throughout the USA, the use of turboprop aircraft continues to grow rapidly. The major airlines are interested in turboprop aircraft as feeders to their long-haul operations. Thus, passenger comfort during the loading and unloading of turboprop passengers is a growing concern. A second growing issue involves the legal requirements for the loading and unloading of handicapped passengers. Both of these issues are pushing the market for passenger loading bridges. The loading bridges being purchased by American Eagle are a modification of existing jetway designs. However, in 1998, Jetway Systems plans to start the development of a new generation of loading bridges designed specifically to accommodate a range of turboprop aircraft. They are considering whether CTR should be included in the range of aircraft for which this new generation loading bridge will be designed.

In the CTRDAC economic analysis, it was recognized that turboprop aircraft are one of several CTR competitors. For lack of any better data, it was assumed that passengers would have no preference between CTR and turboprops. As turboprops become more attractive with the introduction of loading bridges, 40-passenger CTR operations will either have to respond by becoming more attractive as well or accept a loss of market share. This will particularly be an issue in areas where weather is often cold, wet or miserable.

Summary

Will passenger comfort issues cause the use of loading bridges to be viewed as a minimum requirement for operations of the 40-passenger CTR?

Will the laws on the loading and unloading of handicapped passengers require the use of loading bridges as a minimum requirement for CTR commuter operations regardless of aircraft size?

References

No Report Number December 1995	**Civil Tiltrotor Development Advisory Committee - Report to Congress**
McGraw-Hill Companies Aviation Week Group 10/15/95 Article 15477	**American Eagle to Begin Using Loading Bridges at Chicago O'Hare Next Month**

Air Carrier Access Act of 1986

Americans with Disabilities Act (ADA) of 1990

VERTIPORT DESIGN AC REVISION - WHITE PAPER
CTR ROTORWASH EFFECT ON CIVILIAN PASSENGERS
Robert D. Smith, FAA AND-710
April 22, 1997

Background

The majority of civil helicopters are light in weight and it is rare for civil helicopters to cause rotorwash-related mishaps. However, as rotorcraft increase in weight, they are capable of generating greater rotorwash. Anticipating the introduction of tiltrotor and large helicopters (such as the EH-101) at publish facilities, it is appropriate to consider the effect of CTR and large helicopter rotorwash on a different class of civilian passengers. In addition, with the introduction of a 40-passenger CTR, the characteristics of the typical rotorcraft passenger will change significantly. One will need to be concerned with the safety of the grandmother and the two-year old grandchild in tow. How should we design vertiports to address this issue?

The FAA has been considering this issue for several years. Our approach to this task has been four-fold:

a. Measure rotorwash of existing helicopter and vertical flight aircraft such as the tiltrotor. Make use of data collected by military agencies.

b. Develop and validate a rotorwash computer model based on the available rotorwash data.

c. Analyze rotorwash induced mishaps and determine the threshold(s) at which rotorwash becomes a potential hazard.

d. Apply the model to an analysis of a variety of operational scenarios using this threshold(s) and determine how to alleviate this type of mishap by avoiding these potential hazards.

Each of these facets is discussed in the following paragraphs.

Discussion - Rotorwash Measurement

The FAA has collected rotorwash data in an effort to better understand the rotorwash phenomenon and the operational environment at vertical flight landing sites. Extensive rotorwash data have also been collected by other federal agencies on a number of vehicles. These include military data on helicopters, the XV-15 tiltrotor, and preliminary data on the V-22 Osprey. Using the available rotorwash data, the FAA has developed a rotorwash computer model. A user's guide for this program was originally published in FAA/RD-90/25, Rotorwash Computer Model - User's Guide. An updated version of this document was published as FAA/RD-93/31, Rotorwash Analysis Handbook.

Using this computer program, the FAA has modeled the rotorwash expected from a variety of tiltrotor aircraft. Results are documented in FAA/RD-93/31 and in FAA/RD-90/16. Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight. The most significant conclusion of this evaluation was the following:

a. Depending on the various factors involved, ALL evaluated configurations do have the potential to create rotorwash related hazards. These hazards will have to be addressed through vertiport design and vertiport operating procedures.

It is important to note that all of the CTR rotorwash data collected prior to 1997 was for either air-taxi or hover-taxi operations. On the basis of this work, the vertiport Design WG concluded (at the November 25, 1996 meeting) that the rotorwash generated by the hover-taxi or air-taxi of 40-passenger CTR would be so severe that it could not be allowed to occur. In response to this conclusion, the FAA and industry are working to obtain measured ground-taxi rotorwash data on both the XV-15 and the V-22. The XV-15 data

was collected by Bell Helicopter in late winter 1997. FAA is working with the V-22 Program Office to obtain similar measured data on the V-22. The FAA's intention is to use the measured data in correlation with the ROTORWASH model so as to ensure high confidence in the model's output.

Discussion - Analysis of Rotorwash Induced Mishaps

The FAA has analyzed a number of accidents and incidents that were caused by rotorwash. Using the model described in FAA/RD-90/25 and in FAA/RD-93/31, the intent was to identify threshold levels where rotorwash becomes potentially hazardous. This effort is documented in report FAA/RD-90/17, Analysis of Rotorwash Mishaps. For purposes of discussion, let us define two points D and S shown below.

..........D..............................S...................

Consider the continuum of operations that might take place at a vertiport and consider the rotorwash resulting from these operations. Analysis can show that everything to the left of D is dangerous and that everything to the right of S is safe. The definitely dangerous situations can be avoided through vertiport design. The definitely safe situations present no problems. Due to the complexity of the rotorwash issue, however, there is a lot of ground between points D and S where the situation is gray rather than black or white.

Economically, it is probably not practical to preclude (via vertiport design or operational restrictions) all operations that fall between points D and S. It is, after all, the pilot's responsibility to avoid situations that are dangerous. But for CTR commuter operations, it will be appropriate to minimize (via vertiport design or operational restrictions) the risk of all operations that are potentially dangerous.

Anticipating the introduction of large tiltrotor and heavy helicopters at public landing facilities, the FAA has been working to gain a better understanding of the rotorwash phenomenon. By analyzing accidents/mishaps involving rotorwash, the FAA intent is to determine the thresholds at which rotorwash creates a potential hazard in a variety of scenarios. In so doing, it should be possible to reduce the distance between points D and S and to provide an adequate safety margin through vertiport design and operational restrictions.

Due to the lack of detailed mishap data, critical threshold values of rotorwash velocity could not be conclusively identified. However, critical ranges of combined rotorwash and ambient velocity were identified for several types of mishaps investigated. These ranges of peak velocity occur between approximately 30 and 40 knots. For the current efforts of the Vertiport Design Advisory Circular working Group, 30 knots appears to be the appropriate threshold for use in defining the point of potential hazard to passenger and ground personnel. (This topic is addressed in greater detail in a later White Paper.)

Discussion - Analysis of Operational Scenarios

This facet of the rotorwash effort has not yet been initiated.

Summary

With the introduction of tiltrotor and larger helicopters (such as the EH-101) at public facilities, the risk of rotorwash-induced accidents will increase. It would be safer not to depend too heavily on pilot judgment to avoid all potential hazardous situations involving rotorwash. Some potential hazards can best be avoided by implementing operational constraints. Others will be best addressed by precluding the hazard via landing site design.

The intent of this approach has been to develop different gate separation requirements for different operational scenarios. This approach would allow industry to choose among several alternatives in vertiport design: large gate separations allowing independent operations at adjacent gates, smaller gate separations requiring restrictions on passenger loading/unloading at gate A while an aircraft is taxiing to or from the

adjacent gate B, or the use of enclosed jetways/loading bridges for passenger loading/unloading. Still to be resolved are questions whether other factors will cause loading bridges to be considered a minimum requirement for CTR commuter operations rather than an option. These factors include issues of passenger comfort and laws concerning the loading and unloading of handicapped passengers (see other issue papers).

Future R&D - Rotorwash

Rotorwash is an extremely complex phenomenon. While results to date are adequate for use by the Vertiport Design Advisory Circular Working Group, there are some refinements that the Working Group may wish to recommend in preparation for future revision of the AC. The following specific R&D efforts are suggested for the Working Group's consideration:

a. Correlate additional V-22 Osprey rotorwash flight test data with the rotorwash computer program documented in report FAA/RD-93/31. Correlate BB-6609 (previously referred to as the D-600) rotorwash flight test data with the rotorwash computer program. The BB-609 data are of particular interest since the aircraft is expected to have horizontal engine exhausts even in helicopter mode. Based on these data, modify the rotorwash model as appropriate.

b. Acquire rotorwash flight data documenting the effort of both wind and maneuvering near hover. (Without these data, questions will continue to exist with respect to the definition of the worst case scenarios in all safety analyses.) A test plan (RD-92-1-LR) has been developed for this purpose.

c. Determine if a serious hazard potential exists for the entertainment, in the outwash flow field, or small particles from the landing surface (i.e., gravel). Within the industry, there is not a clear consensus on how large gravel has to be before it no longer constitutes a potential hazard when adjacent to a landing site. Rooftop facilities are an issue of particular interest.

d. Conduct flight tests to define acceptable limits of overturning force and moment values for civilian ramp personnel and passengers. A test plan (RD-92-2-LR) has been developed to this purpose.

e. Analyze a variety of operational scenarios using rotorwash safety thresholds and develop alternatives that could prevent rotorwash accidents and incidents.

References

No Report Number December 1995	**Civil Tiltrotor Development Advisory Committee - Report to Congress**
FAA/ND-95/3	**Vertiport Capacity - Analysis Methods**
FAA/RD-93/31,I	**Rotorwash Analysis Handbook: Volume I - Development and Analysis**
FAA/RD-93/31/II	**Rotorwash Analysis Handbook: Volume II - Appendixes**
FAA/RD-93/17	**Safe Helicopters Through Design and Planning - A Summary of FAA Research and Development**
FAA/RD-90/25	**Rotorwash Computer Model - User's Guide** (replaced by FAA/RD-93/31)
FAA/RD-90/17	**Analysis of Rotorwash Effects in Helicopter Mishaps**
FAA/RD-90/16	**Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight**

VERTIPORT DESIGN AC REVISION - WHITE PAPER
ACCESSIBILITY TO INDIVIDUALS WITH DISABILITIES OR SPECIAL NEEDS

Robert D. Smith, FAA AND-710

April 22, 1997

Background

Airport terminal facility design requirements are dictated by various Federal Laws including the Rehabilitation Act of 1973, the Air Carrier Access Act of 1986, and the Americans with Disabilities Act (ADA) of 1990. These requirements have been implemented by 14 CFR Part 382, 49 CFR Part 27, and 49 CFR Part 37. Chapter 7 of AC 150/5360-13, Planning and Design Guidelines for Airport Terminal Facilities, summarizes Congressional requirements imposed on airport terminal facilities to assure full accessibility to individuals with disabilities.

Discussion

14 CFR Part 382, Nondiscrimination on the Basis of Handicap in Air Travel, applies to air carrier airports. Part 382 states that "Air carrier airport means a public, commercial service airport which annually receive 2,500 or more passengers and receives scheduled air service." Thus, the requirements of 14 CFR Part 382 will be applicable to virtually any public vertiport with scheduled service.

49 CFR Part 27, Nondiscrimination on the Basis of Handicap in Programs and Activities Receiving or Benefiting from Federal Financial Assistance, "applies to each recipient of Federal financial assistance from the Department of Transportation and to each program or activity that receives or benefits from such assistance." Thus, the applicable requirements of 49 CFR Part 27 will apply to any vertiport that receives Federal financial assistance such as Airport Improvement Program funding.

49 CFR Part 37, Transportation Services for Individuals with Disabilities (ADA), implements the transportation and related provisions of Titles II and III of the Americans with Disabilities Act of 1990. While the majority of this Part applies to ground transportation facilities under the Federal Highway Administration, new airport construction is specifically addressed in paragraph 10.4.1 of Appendix A. Thus, the applicable requirements of 49 CFR Part 37 will apply to any public vertiport.

Chapter 7 of AC 150/5360-13, Planning and Design Guidelines for Airport Terminal Facilities, summarizes Congressional requirements imposed on airport terminal facilities to assure full accessibility to individuals with disabilities. This concise summary addresses the requirements of 14 CFR Part 382, 49 CFR Part 27, and 49 CFR Part 37.

Currently, the FAA is drafting a stand-alone AC 150/5360-XX, Access to Airport Terminals by Individuals With Disabilities. Publication of AC 150/5360-XX is expected in the next 12 months. Upon approval of this new AC, AC 150/5360-13 will be modified to refer to AC 150/5360-XX. For reasons of administrative efficiency, the Vertiport Design AC should also address this topic by referring to AC 150/5360-XX.

References

Planning and Design Guidelines for Airport Terminal Facilities, AC 150/5360-13 (including Change 1), January 19, 1994

Rehabilitation Act of 1973

Air Carrier Access Act of 1986

Americans with Disabilities Act (ADA) of 1990

Nondiscrimination on the Basis of Handicap in Air Travel, 14 CFR Part 382

Nondiscrimination on the Basis of Handicap in Programs and Activities Receiving or Benefiting from Federal Financial Assistance, 49 CFR Part 27

Transportation Services for Individuals with Disabilities (ADA), 49 CFR Part 37

Attachments

Portions of the following documents are attached:

Planning and Design Guidelines for Airport Terminal Facilities, AC 150/5360-13 (including Change 1), Jan . 19, 1994, pp. 105-106.

Nondiscrimination on the Basis of Handicap in Air Travel. 14 CFR Part 382, selected portions.

Nondiscrimination on the Basis of Handicap in Programs and Activities Receiving or Benefiting from Federal Financial Assistance, 49 CFR Part 27, selected portions.

Transportation Services for Individuals with Disabilities (ADA), 49 CFR Part 37, selected portions.

Excerpt from AC 150/5360-13

CHAPTER 7. ACCESSIBILITY TO INDIVIDUALS WITH DISABILITIES AND SPECIAL NEEDS USERS

116. GENERAL. This chapter summarizes the requirements imposed on airport terminal facilities to assure full accessibility to individuals with disabilities. These requirements are contained in the Americans with Disabilities Act (ADA) of 1990. 14 CFR Part 382, Nondiscrimination on the Basis of Handicap in Air Travel, which implements the Air Carrier Access Act of 1986, and 49 CFR Part 27, Nondiscrimination on the Basis of Handicap in Programs and Activities Receiving or Benefiting from Federal Financial Assistance with implements the Rehabilitation Act of 1973, as amended, and the ADA, and 37, Transportation Services for Individuals with Disabilities (ADA), which implements the ADA within the air transportation industry, include conditions applicable to air terminal buildings.

117. MINIMUM BUILDING DESIGN STANDARDS. ADA requirements apply to any facility occupied after January 26, 1993 for which the last application for a building permit or permit extension is certified as complete after January 26, 1992. 49 CFR Part 27 requires new airport terminal facilities designed and constructed with Federal funds to meet the ADA standards set forth in Appendix A of 49CFR Part 37.

118. SPECIFIC REQUIREMENTS FOR AIRPORT TERMINALS. In addition to meeting minimum ADA building standards, 49 CFR Part 27 imposes the following facility and equipment requirements for new airport terminals:

a. That the basic terminal design shall permit efficient entrance and movement of persons with disabilities, while at the same time giving consideration to their convenience, comfort, and safety. It is essential that the design, especially concerning the location of elevators, and similar devices, minimize any extra distance that wheelchair users must travel compared to persons without a disability to reach ticket counters, waiting areas, baggage handling areas, and boarding locations.

b. That the international accessibility symbols is displayed at accessible entrance to terminal buildings.

c. That the ticketing system is designed to provide persons with disabilities with the opportunity to use the primary fare collection area for purchasing tickets.

d. That baggage areas are accessible to persons with disabilities, and the facility is designed to provide for efficient handling and retrieval of baggage by all persons.

e. That boarding by jetways and by passenger lounges are the preferred methods for movement of persons with disabilities between terminal buildings and aircraft. Where this is not practicable, operators may accommodate this requirement by providing lifts, ramps, or other suitable devices not normally used for movement of freight, which are available for enplaning and deplaning wheelchair users.

f. That at each public telephone center in a terminal, at least one clearly marked telephone is equipped with a volume control or sound booster device and with a device available to persons with disabilities, which makes telephone communication possible for persons with hearing impairment and/or using wheelchairs.

g. That each airport ensures that there is sufficient teletypewriter (TTY) service to permit hearing-impaired persons to communicate readily with airline and other airport personnel.

Excerpt from AC 150/5360-13

h. That several spaces adjacent to the terminal building entrance, separated from the main flow of traffic, and clearly marked, are made available for the loading and unloading of passengers with disabilities from motor vehicles; and that the spaces allow individuals in wheelchairs or with braces or crutches to get in and out of automobiles on to a level surface suitable for wheeling and walking.

i. That curb cuts or ramps with grades not exceeding 8.33 percent are provided at crosswalks between parking areas and the terminal.

j. That in multi-level parking, ample and clearly marked space is reserved for ambulatory and semi-ambulatory individuals with disabilities on the level nearest to the ticketing and boarding portion of the terminal facilities.

k. That in multi-level parking areas, elevators, ramps, or other devices which can accommodate wheelchair users are easily available. [Note: AC 150/5220-21, Guide Specifications for Lifts Used to Board Airline Passengers with Mobility Impairments, should be consulted for additional information in this matter.]

l. That the environment in the waiting area/public space of the airport terminal facility gives confidence and security to the person with a disability using the facility. This means that not only is the space to be designed to accommodate individuals with a disability, but that it is also to contain clear directions for using all passengers facilities.

m. That airport terminal information systems take into consideration the needs of individuals with disabilities. Although the primary information mode required is visual (words, letters, or symbols), using lighting and color coding, airport terminals are also required to have facilities providing oral information.

n. That public service facilities, such as toilets, drinking fountains, telephones, travelers aid, and first-aid medical facilities are designed in accordance with the Uniform Federal Accessibility standards (UFAS), as supplemented or superseded by the ADA Accessibility Guidelines (ADAAG) set forth in 49 CFR Part 37, Appendix A.

119. EXISTING TERMINALS. The ADA of 1990 requires all existing terminals to have incorporated the required non-structural accessibility features by January 26, 1992. Structural changes should be accomplished as soon as practicable, but no later than January 26, 1995.

120. OTHER USERS WITH SPECIAL NEEDS. Some airport terminals may serve significant numbers of older travelers, families traveling with infants or your children, or others, not normally considered having a disability, but having special facility and services requirements.

a. Higher proportions of older travelers may warrant more seating in gate lounge and terminal waiting areas than otherwise provided. Mobility aid such as moving walkways or airline courtesy carts may be more frequently justified, and may require wider concourse designs. However, slightly slower moving rates may be necessary to facilitate access and egress, and keeping anxiety at a minimum. Emphasis on appropriate lighting, high visibility signing and other public information systems may also be warranted.

b. Airports serving major tourism areas are likely to accommodate increased numbers of children. Passengers waiting areas may be designed with space for children to play. Public lavatories, drinking fountains, and other amenities should be easily accessible by children. The provision of diaper changing, baby bottle warming, and private infant feeding facilities should be considered.

121. - 130. RESERVED.

APPENDIX C.
VERTIPORT DESIGN REFERENCES
DOCUMENTS OF INTEREST TO THE WORKING GROUP

FAA Technical Reports

*FAA/ND-98/1	**Heliport Lighting – Technology Research** (Ralph D. Kimberlin, J. Paul Sims, Thomas E. Bailey)
*FAA/ND-98/2	**Heliport Lighting – Configuration Research** (Scott Fontaine, Adina Cherry)
FAA/ND-98/3	**Heliport Operations in an Obstacle-Rich Environment (ORE)** (Brian M. Sawyer, Eric H. Bolz, James M. Daum, James F. Grenell, Paul R. Wilkinson, Leon A. Zmroczek, Arthur F. Kramer)
*FAA/ND-98/4	**Heliport Lighting – U.S. Park Police Demonstration** (Scott A. Fontaine)
FAA/ND-96/1	**Heliport/Vertiport Implementation Process - Case Studies** (Deborah J. Peisen, Robert M. Winick, Stephen V. Berardo, J. Richard Ludders, Samuel W. Ferguson)
FAA/ASD410-95-002	**Civil Tiltrotor Terminal Area Route Development Study** (Jasenka Rakas, Stephane Mondoloni, N. Mariano Perigotti, William E. Weiss)
*FAA/ND-95/3	**Vertiport Capacity - Analysis Methods** (Yeon-Myung Kim, Paul Schonfeld, Jasenka Rakas)
FAA-AOR-100-94-001	**Civil Tiltrotor Market Penetration Effects on Northeast Corridor Airport Delay** (Anny Cheung, Douglas Baart)
FAA-AOR-100-94-008 MTR 94W0000150	**Effects of Civil Tiltrotor Service in the Northeast Corridor on En Route Airspace Loads** (Dr. William W. Trigerio, Xavier P. Szebrat, Stephanie B. Frazier)
FAA/RD-94/10	**Vertiport Characteristics** (J. Richard Ludders, Stephen V. Berardo, Richard J. Dyment, Deborah J. Peisen)
FAA/CT-94/120	**Evaluation of Retro-reflective Beads on Airport Pavement Marking** Keith W. Bagot
FAA/AOR-100/93/013	**Civil Tiltrotor Northeast Corridor Delay Analysis (Based on the Demand Scenario Described in *Civil Tiltrotor Missions and Applications Phase II: The Commercial Passenger Market*)** (Michael A. Fabrizi, Stephanie B. Fraser, A. Lucille Springen, William W. Trigerio)
*FAA/RD-93/17	**Safe Heliports Through Design and Planning - A Summary of FAA Research and Development** (Robert D. Smith)
*FAA/RD-93/31,I	**Rotorwash Analysis Handbook: Volume I - Development and Analysis**
*FAA/RD-93/31,II	**Rotorwash Analysis Handbook: Volume II – Appendixes** (Sam Ferguson)
FAA/RD-93/37	**Analysis of AIP Funded Vertiport Studies** (Deborah Peisen et al.)

* Indicates key documents of interest

*FAA/RD-90/17	**Analysis of Rotorwash Effects in Helicopter Mishaps** (Sam Ferguson)
*TR 4-67, Sept. 1967	**Development Study for a Helipad Standard Marking Pattern**

Other Technical Documents

***Evaluation of Two Cockpit Display Concepts for Civil Tiltrotor Instrument Operations on Steep Approaches** (William A. Decker, Richard S. Bray, Rickey C. Simmons, George E. Tucker), presented at the Piloting Vertical Flight Aircraft: A Conference on Flying Qualities and Human Factors, San Francisco, CA, January 1993 (American Helicopter Society Conference).

***Piloted Simulator Investigations of a Civil Tilt-rotor Aircraft on Steep Instrument Approaches** (William A. Decker), presented at the American Helicopter Society 48th Annual Forum, Washington DC, June 3-5, 1992.

***Flight Simulation – Where are the Challenges?** (William A. Decker, Rickey C. Simmons, George E. Tucker), AGARD-CP-577, presented at the Flight Vehicles Integration panel Symposium, Braunschweig, Germany, May 22-24, 1995.

***VMS Simulation of a Variable Diameter Tiltrotor** (Karen Studebaker, William A. Decker, David G. Matuska, Patrick M. Morris, M. Todd Smith), presented at the American Helicopter Society 53rd Annual Forum, Virginia Beach, April 29 – May 1, 1997.

***Flight Director and Approach Profile Development for Civil Tiltrotor Terminal Area Operations** (Peter Klein, Colby Nicks, presented at the American Helicopter Society 54th Annual Forum, Wash DC, May 1998.

Advisory Circulars

*AC 150/5220-30A	**Airport Winter Safety and Operations**
*AC 150/5300-13	**Airport Design** (Including Change 5), Feb 14, 1997
*AC150/5320-6	**Airport Pavement Design and Evaluation**
*AC 150/5340-1G	**Standards for Airport Marking**, Sept. 27, 1993
*AC 150/5345-12C	**Specifications for Airport and Heliport Beacons**
*AC 150/5360-9 April 1980	**Planning and Design of Airport Terminal Building Facilities at Nonhub Locations**
*AC 150/5360-13 January 19, 1994	**Planning and Design Guidelines for Airport Terminal Facilities** (including Chg. 1)

Other Documents

* December 1995	**Civil Tiltrotor Development Advisory Committee – Report to Congress**
*FAA Order 5050.4A	**Airport Environmental Handbook**
*FAA Order 8260.42B	**Helicopter Nonprecision Approach Criteria Utilizing the Global Positioning System (GPS)**

* Indicates key documents of interest

APPENDIX D.
HELIPORT DESIGN WHITE PAPERS

This appendix contains these white papers arranged in the following order:

Dec. 2, 1999	**Heliport Design Rationale,** Robert D. Smith, FAA
Aug. 2, 1999	**Local Zoning Regulations - A Historical Perspective as a Foundation for a Discussion of State Heliport Design Regulations,** Robert D. Smith, FAA
June 18, 1999	**Hospital Heliports – FAA Design Recommendations, A Historical Perspective,** Robert D. Smith, FAA
Oct. 22, 1998	**Heliport Design Issue Papers – Overview,** Robert D. Smith, FAA
Oct. 22, 1998	**Application of Transition Surfaces at Various Classes of Heliports,** Robert D. Smith, FAA
Oct. 22, 1998	**The Benefits of More Than One Approach/Departure Path,** Robert D. Smith, FAA
Oct. 22, 1998	**Vertical Dimensions of the Approach/Departure Surfaces,** Robert D. Smith, FAA
Oct. 22, 1998	**"Object Penetrations" of the Approach/Departure Surface and the Transition Surfaces Versus "Hazards to Air Navigation"** Robert D. Smith, FAA
Oct. 22, 1998	**Marking and Lighting of Obstacles Adjacent to the Approach/Departure Path,** Robert D. Smith, FAA
Sept. 1990	**Enter at Your Own Risk,** Keith Engelsman
Sept. 1990	**Crew Confusion Leads to Trouble**
July 1991	**The Philosophy and Realities of Autorotations,** Michael Hynes

HELIPORT DESIGN RATIONALE
Robert D. Smith, FAA, AND-520
December 2, 1999

1. INTRODUCTION. In the interest of being concise, an FAA facility design advisory circular (AC) could simply recommend the dimensions and details of the particular design parameters of interest. In many cases, however, the unique characteristics of the particular location and facility may make it difficult to apply the design recommendations. This is why some FAA facility design AC's include a section addressing the design rationale associated with some of the more essential issues. Historically, the FAA Heliport Design AC included material addressing the design rationale. At some point, this material was deleted. This presents certain problems in interpreting the intent of the AC's recommendations. Particular variation has been seen in the interpretations of state and local authorities throughout the country. Addressing the design rationale would help clarify how the AC should be applied in specific situations.

2. BACKGROUND. Over the last several decades, this advisory circular (AC) has been developed and modified with the participation of Industry. Proposed revision have been extensively debated and considered on both a technical and a political basis. During any revision, Industry argues vigorously to ensure that none of the AC's recommendations exceed the absolute minimum requirements. Thus, if a particular heliport does not meet the recommendations of the Heliport Design AC, the owner and the operator should analyze it for potential safety hazards. Analysis may show how it could be modified to increase the associated safety margin. As an alternative, analysis may identify ways to accomplish the same safety objectives by placing restrictions on the helicopters that operate at the facility or the associated operational procedures.

3. SAFETY AREA. A Safety Area surrounds a FATO. The purpose of a Safety Area is twofold. First, it is intended to reduce the risk of damage to a helicopter that has been caused to move off the FATO by the effect of turbulence or crosswind, mis-landing or mis-handling. Second, it is intended to protect people and property on the ground by providing a clear area.

4. VFR APPROACH/DEPARTURE PATHS. The purpose of approach/departure airspace is to provide sufficient airspace clear of obstacles to allow safe approaches to and departures from landing sites. The VFR approach/departure airspace of Figure 2-7 is intended to allow safe operations under a wide range of scenarios (temperature, percent of maximum gross weight, etc. at the landing site elevation). This airspace is also intended to allow the pilot to approach and depart without going through the "avoid portion" of the helicopter's height/velocity (H/V) diagram. For some helicopters, additional approach/departure airspace may be desirable.

5. ORIENTATION AND NUMBER OF APPROACH/DEPARTURE PATHS.

a. Wind is a factor to consider in choosing approach/departure path orientation. An accurate wind analysis provides heliport planners and designers with a means on which to base this determination. Appendix 1 of AC150/5300-13 provides guidance on how such an analysis may be conducted.

b. The most desirable orientation of approach/departure paths is the one that provides the largest wind coverage and the minimum crosswind and tailwind components while still providing the recommended clear approach/departure airspace. Wind coverage is the percent of time that crosswind and tailwind components are below an acceptable value.

c. Approach/Departure Paths - Number and Orientation. The proper selection of approach/departure paths allows downwind operations to be avoided and crosswind operations to be kept to a minimum. This may be accomplished with a separation of at least 135 degrees between two or more approach/departure paths. With only one approach/departure path, circumstances may lead a pilot to fly either the approach or the departure with a tail wind. For this reason, two paths provide greater operational

flexibility and a larger safety margin. A second approach/departure path also provides clear airspace for a missed approach if the pilot finds that this is necessary.

6. PROTECTION ZONE. The protection zone is the area under the approach/departure path starting at the edge of the FATO and extending out for a distance (See Figures 2-8 and 3-7). In the event of an engine failure, the protection zone provides an emergency landing site that would minimize the risk of injury or damage to people or property on the ground. At PPR heliports, it is often impossible to own or control all of the property containing the protection zone. When this is the case, the heliport proponent may take other steps to keep the area clear of incompatible objects, to preclude the congregation of people, and to minimize the risk of injury or damage to property on the ground in the event of an engine failure. A formal or informal agreement with the property owners could be a way of accomplishing this.

7. PARKING AREAS. If a parking are is designed for "back out' operations, controls may be established to ensure that pilots do not back into some fixed or mobile object. In particular, controls could be established to ensure that two helicopters do not back out at the same time. If this can not be accomplished, other parking area designs can be used to achieve a higher safety margin.

8. HELICOPTER FUELING. Helicopter fueling is typically accomplished with the use of a fuel truck or the use of a specific fueling area with stationary fuel tanks. When stationary fuel tanks are used, there are several potential problems that can be avoided through proper design.

a. Accident analysis has identified cases where helicopters collided with the dispensing equipment. Apparently, the pilot was trying to park very close to avoid shutting down the engine and then finding that the fueling hose would not reach the fuel tank. Fueling areas can be designed to avoid this problem. One approach is to ensure that there is no object tall enough to be hit by the main or tail rotor blades within a distance of 1.0 OL from the center point of the position where the helicopter would be fueled. If this is not practical at an existing facility, long fuel hoses can be installed so pilots will not be inclined to park too close to the obstacle(s). Accidents can be avoided by marking the refueling position and the centerline of the path to this refueling position in a way that provides adequate tip clearance.

b. While long fuel hoses mitigate the risk of a collision with an obstacle during ground maneuvering, they present other problems. Long hoses generally suffer more wear and tear than short hoses. This raises concerns about the environmental hazards of leaking hoses and the more frequent hose replacement required to address this issue. Excessively long hoses also present a tripping hazard if they are not restored to their proper position after every use.

c. Fueling Area Lighting. Pilots have a more difficult time judging tip clearances at night. For this reason and others, lighting the fueling area helps to provide pilots with visual cues when night fueling operations are contemplated. Proper location of lighting can ensure that any light poles do not constitute an obstruction hazard.

10. HELIPORT LIGHTING. During daytime VFR operations, the pilot flies a heliport approach using a very wide range of visual cues provided by the heliport marking and lighting and by the surrounding terrain, buildings, roads, etc. These cues include: acquisition, lateral guidance (line-up), glideslope, horizon, closure rate, and touchdown. However, during VFR night and marginal VFR operations, the available visual cues may be very limited. At such times, heliport lighting helps to provide these visual cues.

a. Visual Acquisition Cues. Visual acquisition includes identification of the location as a heliport and rapid acquisition in marginal VFR conditions. During nighttime operations in clear weather, the heliport lights enable the pilot to visually acquire the facility at a distance of several miles. This lighting is intended to be adequate to support rapid visual acquisition during marginal VFR weather. A heliport beacon is the typical means for providing this acquisition guidance.

b. Lateral Guidance Cues. During the approach, visual cues enable the pilot to stay on the centerline of the approach path. This is particularly important if there are obstacles in the vicinity. Various means may be used to provide this guidance including:

(1) FATO Edge Lights. If the FATO is rectangular and the sides of the FATO are parallel to the approach path, FATO edge lights can provide lateral guidance during the approach.

(2) On rooftop heliports, lateral guidance may be provided by a lighted FATO centerline and a lighted vertical line on the side of the building. When this arrangement is used, the two lines of light are installed so that they look like a straight line when the pilot is flying on the approach centerline.

(3) Approach Lights.

(4) Lead-in Lights.

c. Visual Glideslope Cues. A visual approach slope indicator (VASI) is sometimes installed to provide the pilot with relative altitude and obstacle clearance. When installed a VASI is located outside the safety area in a position that guides the helicopter to the TLOF. To avoid dazzling a pilot during approach, landing, and taxiing operations, the VASI can be provided with an intensity control to allow adjustment to meet prevailing ambient lighting conditions. A VASI may be the best way to ensure safe operations where an aeronautical safety analysis has determined that it is difficult to judge the correct approach angle because:

(1) There are inadequate visual references

(2) Deceptive surrounding terrain produces misleading information. For example, a nighttime approach over water or a forested area can lead a pilot to fly below the appropriate approach angle.

(3) Obstacle clearance, noise abatement, or traffic control procedures require a particular approach slope to be flown.

d. Horizon Cues provide the pilot with roll guidance during approach. Such guidance is particularly important if there are inadequate visual references of if deceptive surrounding terrain produces misleading information. Various means may be used to provide this guidance including:

(1) FATO Edge Lights. If the FATO is rectangular and the sides of the FATO are parallel to the approach path, FATO edge lights can provide horizon guidance during the approach.

(2) On rooftop Heliports, horizon guidance may be provided a lighted FATO centerline and a lighted vertical line on the side of the building. When this arrangement is used, the two lines of light are installed so that they look like a straight line when the pilot is flying on the approach centerline.

(3) Perimeter Light Extensions. Extensions increase the strength of the visual cues by providing a longer line of lights.

(4) Approach Lights.

e. Closure Rate Cues allow the pilot to decelerate prior to touchdown. Various means may be used to provide this guidance including:

(1) FATO Edge Lights.

(2) TLOF Edge Lights.

(3) Perimeter Light Extensions.

(4) Approach Lights.

(5) Flood Lights.

f. Touchdown Cues include transition to hover cues, hover position cues, hover altitude cues, and hover altitude rate cues. Various means may be used to provide this guidance including

(1) TLOF Edge Lights.

(2) TLOF Centerline Lights.

(3) Flood Lights.

g. Commentary. While the various parts of this paragraph discuss different ways to provide visual cues, these methods provide cues of different strengths from strong to weak.

11. PERIMETER LIGHTING. The Heliport Design AC states that a circular FATO or TLOF may be outlined with a circular pattern of lights. When a TLOF is circular in order to minimize cost, the FATO may be circular as well. While this is common practice, there is a better option. At a distance during nighttime operations, a square or rectangular pattern of FATO edge lights provides the pilot with much better visual cues than a circular pattern. Thus, a square or rectangular pattern of FATO edge lights should be installed even if the TLOF is circular.

12. ELECTROLUMINESCENT LIGHTING. Electroluminescent (EL) panels can be an effective technology for lighting that does not need to been seen at a great distance. For example, EL panels can effectively illuminate the edges and centerlines of heliport parking areas. If the FATO edges are marked with lights that can be seen at several miles distance, EL panels can effectively mark the TLOF edges. EL panels are significantly brighter when powered by a 400 Hz power source rather than the typical 60 Hz electrical power. However, during the approach, EL panels are not adequate to provide visual acquisition of the heliport, horizon guidance, or lateral guidance.

13. MARKING AND LIGHTING OBJECTS CLOSE TO THE APPROACH/ DEPARTURE PATH. Consider the case of a wire perpendicular to the approach/departure path, just a few feet beneath the approach/departure surface at 3800 feet (1158 m) from the facility. Such a wire would constitute a hazard. If removal is impractical, marking can make it more conspicuous during the day. For operations between dusk and dawn, lighting can make such an obstacle conspicuous. Bear in mind that, in many cases, the top of this object may be much higher than 200 feet (61 m) above ground level (AGL). In such cases, there could be a compelling rationale to mark and light such objects even if the nearest airport or heliport was several miles away. However, in a case where there is rising terrain, a pilot might be on the approach/departure surface at 3800 feet (1158 m) from the heliport and still be less than 200 feet (61 m) AGL. A power line crossing just a few feet beneath the approach/departure path would constitute a hazard even though it was less than 200 feet (61 m) AGL. Regretfully, in spite of a large number of wire-strike accidents, Industry has not made significant progress in marking and lighting such objects in close proximity to heliport approach/departure paths.

LOCAL ZONING REGULATIONS – A HISTORICAL PERSPECTIVE AS A FOUNDATION FOR A DISCUSSION OF STATE HELIPORT DESIGN REGULATIONS

Robert D. Smith, FAA, AND-520

August 2, 1999

Local Zoning Regulations

Consider the individual who owns a single-family home and has lived there for decades. Right next door is a very large piece of undeveloped property. The owner died recently and the property was sold by her estate. The new owner plans to use this property for a pig farm, or a sewage treatment plant, or an apartment complex including two dozen 18-story buildings, or a mall with 500,000 square feet of commercial floor space and 20,000 parking spots. Sounds like a nightmare? To a large degree, such nightmares are either precluded or mitigated by local zoning regulations.

Local zoning regulations are based on enabling legislation at the state level. The movement toward this type of regulation started in the early 1920's. Basically, the idea was that it would be better to group various land uses geographically. Thus, commercial land use areas would be separated from residential land use areas. High density residential housing would be separated from single-family housing. It was an idea that people supported in the 1920's and one that is still widely supported seventy years later. Prior to the 1920's, local zoning regulations were in place in only a handful of large cities (like New York City). By the early 1970's, approximately 50 percent of cities and towns in the USA had developed local zoning regulations. By the late 1990's, approximately 90 percent of cities and towns in the USA have developed local zoning regulations.

The acceptability of zoning regulations is dependent on the attitudes of the general population. While such regulations are in widespread use in the USA, this use is not universal. For example, zoning has not been widely accepted in many areas in the Western USA where people often have the perspective that they ought to be able to do whatever they want to do with "their land". As the only major city without local zoning regulations, Houston TX is an example of this. In discussions of zoning regulations, city planners often point to Houston to show what happens in the absence of such regulations. Many argue that, in the absence the central planning associated with zoning, Houston is an ugly city. (It should be noted that Houston does have a requirement that you obtain a permit before you can do certain things with your land. Restrictive covenants also place constraints on what can be done with the land in different areas of the city. However, permits and covenants are often less constraining and less effective than zoning regulations.)

Some cities in the Southwest **require** that new buildings above a certain height have a helicopter landing site on the roof. These local building regulations grew out of the experience of rooftop evacuations during certain high rise building fires. In contrast, New York City prohibits roof top heliports under all circumstances based on a 1977 accident at the Pan Am Building rooftop heliport in Manhattan. (This accident spread debris over an area roughly 4 city blocks wide and 6 city blocks long. Two blocks from the accident, one pedestrian on the corner of Madison Avenue and 43rd Street was killed and another was seriously injured when they were struck by a section of the rotor blade that was over 2 feet long.) These local building regulations differ dramatically and yet both are based on traumatic experiences that led the public to demand and support new regulations

State Heliport Design Regulations

The Federal Aviation Administration does not have the statutory authority to regulate the design of private airports, vertiports, or heliports. This limitation in the FAA charter is based on Constitutional limitations placed on the Federal Government. The design regulation of these private facilities comes under the authority of the states. Since roughly 98 percent of US heliports are private, the states have the authority to adopt design regulations for the vast majority of heliports. Some states have exercised this authority, developed a significant body of heliport regulations that apply to all types of heliports, and have a staff of people to enforce these regulations. Some states have exercised this authority, developed a small body of

heliport regulations that apply to some types of heliports, and have an individual who enforces these regulations to the extent that time and resources allow. Some states have no heliport regulations at all.

Throughout the USA, public attitudes toward helicopters and heliports vary. In some parts of the country, people have demanded/supported state heliport regulations for reasons similar to those that led to zoning regulations. They want to protect their investment (in their residence or their office building) and they want to protect themselves from the noise, the privacy intrusion, and the perceived safety risks associated with helicopters. Thus, the existence or lack of state heliport regulations is often a function of the desires of the public.

Texas is a state that proudly announces that they do not regulate heliports in any way. Many Texans are concerned about their "right to do whatever they want with their land" and they are apparently willing to accept the consequences when their neighbors do something undesirable with the adjacent land. The desire to have the state government protect them from the actions of their neighbors does not appear to be a strong in Texas. Thus, in a state like Texas, it seems unlikely that state heliport regulations will be developed in the foreseeable future.

Another factor involves the number of existing heliports. As an example, Wyoming has only three heliports. One could question whether the problems to be avoided through the use of heliport regulations are smaller in scale that the cost associated with developing and enforcing such regulations.

State heliport design regulations make sense in states where the citizens want some predictability and some control over what goes on near their homes, schools, and places of work. State heliport design regulations also make sense in states like New York where a high-profile accident has vividly demonstrated that a heliport accident can kill or injure a "third party" who is several blocks away.

Summary

City planners often comment that local zoning helps to keep the worst things from happening but it does not always permit the best things to happen. More recently, zoning regulations in some areas have been structured as a list of both minimum requirements and goals. This provides a developer greater flexibility but this flexibility comes with additional requirements. In this way, developers are encouraged to do more, on whatever issues are of particular concern to the local authorities, in return for greater flexibility on other issues.

Current FAA heliport design recommendations are largely a matter of "one-size-fits-all". From a standardization perspective, there is something to be said for a high degree of design consistency between the vast majority of heliports in the country. In recent FAA/Industry discussions, however, it has become clear that the wide variety of helicopter missions and heliport environments argue against one-size-fits-all. As an example, the lighting needed for nighttime operations at the Wall Street Heliport in Manhattan differs significantly from what is needed for nighttime operations at a private heliport at a western Kansas farm.

It seems clear to both FAA and Industry that FAA heliport design recommendations need to address the different requirements of various heliport environments. How do we find and maintain the right balance between flexibility and standardization? How can we express this in a way that the minimum heliport design recommendations are clear and unambiguous without being excessive? How do we develop more sophisticated guidance without making the advisory circular so complicated that it becomes difficult to understand? How do we encourage a gradual improvement in the safety margin provided by good heliport design? These are among the challenges that the FAA and Industry face over the next several years.

HOSPITAL HELIPORT - FAA DESIGN RECOMMENDATIONS
A HISTORICAL PERSPECTIVE

Robert D. Smith, FAA, AND-520

June 18, 1999

INTRODUCTION

This white paper discusses some of the historical background that led to the development of FAA hospital heliport design recommendations. It raises issues about the adequacy of these recommendations, asks questions about what should be done to improve the safety of hospital heliports, and articulates the need for a source of funding to pay for such improvements.

BACKGROUND – PAN AM ROOFTOP HELIPORT ACCIDENT

On May 16, 1977, the right landing gear of a New York Airways, Inc., Sikorsky S-61L failed while the helicopter was parked, with rotors turning, on the rooftop heliport of the Pan Am Building in New York City. At the time of the accident, passengers were boarding. The four passengers and three crewmembers already onboard received minor or no injuries. However, four passengers who were outside the aircraft waiting to board were killed and one passenger was seriously injured. One pedestrian on the corner of Madison Avenue and 43rd Street was killed and another was seriously injured when they were struck by a separated portion of one of the main rotor blades. (At approximately two blocks from the accident, they were hit by a section of the rotor blade that was 2 foot, 3 inch in length.)

Two automobiles located on the streets below the accident site were damaged by separated main rotor blade leading edge counterweights. An office on the 36th floor of the west side of the Pan Am Building was extensively damaged when an 11-foot section of a main rotor blade penetrated a window. The New York Airways passenger waiting/control tower area located in the east corner of the heliport had five windows shattered and a light fixture knocked from its structure. A six-foot section of the rooftop edge railing on the north side was penetrated and bent outward by a main rotor blade section.

With the collapse of the landing gear, the helicopter rolled over on its right side and was substantially damaged. The five color-coded main rotor blades struck the surface of the heliport and fractured. Each blade was 28 feet 10 inches long and weighed 209.3 pounds. The outboard sections of the five rotor blades were thrown from the heliport. These outboard sections, including the tip caps, were recovered in the area below the heliport, on the roofs of lower buildings or at street level. The longest distance traversed by the blade portions was 4 blocks north and 1 block west of the Pan Am Building. [Appendix D of the National Transportation Safety Board (NTSB) report no. NTSB-AAR-77-9 shows a wreckage distribution chart. Of a total of 25 pieces, only 2 were recovered on the roof of the Pan Am Building. The remaining 23 pieces were thrown from the roof. The NTSB wreckage chart shows a distribution roughly 4 city blocks wide and 6 city blocks long.]

COMMENTARY ON THE PAN AM HELIPORT ACCIDENT

In the aftermath of the accident, this rooftop heliport was permanently closed and City regulators decided that there would be no other rooftop heliports in New York City. Twenty years afterwards, Federal Aviation Administration (FAA) discussion with City regulators indicated that this prohibition was still in effect and that they intended to enforce a long-term continuation of this policy.

This single accident has had a profound effect, not only throughout the USA but also internationally. It would be difficult to overestimate the number of rooftop heliports that have been precluded as a result of this accident. The death of four boarding passengers was tragic, but the flash point in this matter was the

death of one pedestrian and the injury of a second pedestrian. In choosing any form of transportation, the passengers consciously or unconsciously accept the associated risk of an accident. However, these pedestrians had accepted no risk of an aviation accident in walking the New York City sidewalk. This is why there was such a public reaction to the Pan Am accident. "Third-party" liability is an issue that the helicopter industry can not afford to ignore. (In this context, third parties are anyone besides aircraft passengers or crew members.) The vertical flight Industry has good reason for trying to avoid future accidents that could cause the same type of public reaction that was caused by the Pan Am accident.

BACKGROUND – EMS HELICOPTER ACCIDENT HISTORY

In the USA, the first commercial emergency medical service (EMS) operation began in 1972. Since that time, the number of patients transported annually has grown dramatically. In 1984, the aviation community began to discern a significant rise in number of EMS accidents. In 1986, 14 major EMS helicopter accidents destroyed or substantially damaged 9 percent of the total commercial EMS helicopter population, killing 13 EMS helicopter occupants, and causing serious injury to 5 other occupants. At this point, the National Transportation Safety Board (NTSB) decided to undertake a safety study to examine the accident rates and safety factors related to commercial EMS helicopter operations. The following are some of the many conclusion of this study. (The numbering shown below is the same as used in NTSB report no. NTSB/SS-88/01.)

2. The accident rate for commercial EMS helicopters involved in patient transport missions is slightly less than twice the accident rate of 14 CFR Part 135 nonscheduled air taxi helicopter operators, and approximately 1 ½ times the accident rate of all turbine helicopters from 1980 to 1985; the fatal accident rate for EMS helicopters for this period is approximately 3 ½ times that of 14 CFR Part 135 nonscheduled helicopter air taxis and of all turbine helicopters; the injury accident rate for EMS helicopters is slightly less than that of commercial air taxis and of all turbine helicopters.

3. From 1978 to 1986, the Safety Board investigated 59 commercial EMS helicopter accidents; 19 of these were fatal accidents in which a total of 53 people died; 19 were pilots, 28 were medical personnel, and 6 were patients.

4. Weather-related accidents are the most common and the most serious type of accident experienced by EMS helicopters, and are also the most easily prevented. Twenty-five percent of the 59 accidents investigated by the Safety Board (1978-1986) involved reduced visibility/spatial disorientation as a factor; 73 percent of these were fatal. Reduced-visibility accidents account for 61 percent of all fatal commercial EMS accidents. All of the reduced-visibility accidents in the Safety Board's database occurred during a patient transport mission.

6. All of the 15 reduced-visibility weather-related accidents occurred in uncontrolled airspace at low altitude.

12. Pilot fatigue has been identified as a factor in only one commercial EMS helicopter accident. However, commercial EMS helicopter pilots work in a high-stress environment with rotating shifts; this predisposes them to acute and chronic fatigue.

15. EMS helicopter flying is both a challenging and a stressful occupation. Pilots are often under self-imposed and externally-imposed pressure to complete EMS missions. These pressures can negatively influence pilot judgment.

16. Most hospitals participate in the EMS interior configuration design and specify the type of medical equipment installed. The suitability of this equipment for the aviation environment is

often not considered, since no technical design standards or performance standards relative to the aviation environment exists for this equipment.

24. EMS helicopter program management is often composed of two structures: the 14 CFR Part 135 operator, which manages the pilots, and the hospital, which manages the medical personnel and day-to-day operations. The interface of these two management structures is less than ideal, since pilot management is often not on-site and the hospital program management has no control over the pilots.

25. Hospital EMS program management can have significant impact on the program's safety. Effective communication between the helicopter operator management and the hospital EMS program management is essential to safe EMS helicopter operations.

26. Competition between EMS helicopter programs can adversely impact safety of the programs' operations.

COMMENTARY ON THE EMS HELICOPTER ACCIDENT HISTORY

During the mid-1980's, a number of EMS helicopter pilots complained publicly that hospital management had threatened to fire them if they did not fly a particular visual flight rules (VFR) mission in instrument flight rules (IFR) weather. Some pilots refused the missions and were fired. Some pilots accepted missions they should have declined. A number of pilots and helicopter maintenance personnel complained that many EMS helicopter programs were understaffed and that they were working excessively long hours and experiencing chronic fatigue as a result. Pilots also complained that hospital management was making, or forcing pilots to make poor decisions on aeronautical operational issues and that these managers were unqualified to supervise aviation operations as they were doing.

Coupled with the high EMS helicopter accident rate, these pilot complaints brought the EMS industry a great deal of attention from the media, from hospital administrators, from Congress, from the NTSB, and from the FAA. Based on NTSB recommendations and on an intensive FAA inspection of EMS helicopter programs, the aviation community and the medical community took a number of actions and cut the EMS helicopter accident rate significantly. But the pain involved with so many fatal accidents traumatized many of the people involved in the EMS industry (both pilots and medical personnel) and led to a distrust that remained for years in some hospital EMS programs.

BACKGROUND – HELICOPTER ACCIDENTS AT HOSPITALS

On several occasions, representatives from the air ambulance helicopter community have stated publicly that there have been only a very few accidents at hospital heliports, that all of these have been minor accidents, and that current FAA hospital design recommendations are adequate. While the FAA has not done a thorough accident analysis of heliport accidents since the early 1990's, a very quick look at NTSB accident files has identified the following air ambulance helicopter accidents at hospitals. The text below is taken from NTSB reports.

1. The helicopter contacted power lines and the terrain during an attempted takeoff from a hospital after a cancelled med-evac flight. The hospital is located in a box canyon surrounded by high terrain and power lines. The pilot was aware of the power line that crossed the proposed flight path. (Editorial comment: The pilot had just flown over these wires on the approach to the hospital.) A passenger stated, after the accident, that the pilot hovered back to the end of the landing area to initiate the takeoff. The helicopter struck the unmarked power lines during climbout and descended to ground impact. A witness described the weather as cold and clear with calm ground winds near the hospital. They also stated that the night was bright because of a full moon. **[This was a fatal accident.]** DEN86FA054

2. The aircraft had just discharged two passengers on the rooftop helipad and was preparing for departure. The aircraft was picked up to a hover and the tail rotor struck a heliport surface perimeter light. The tail rotor separated from the aircraft and the aircraft rotated to the right. Throttles were reduced to stop the rotation and the aircraft settled back down to the helipad. The aircraft bounced side to side and rolled off the helipad and came to rest on its left side. The pilot exited and extinguished a small fire that had started near the engine exhaust. **[This was a near-fatal accident.** When the helicopter rolled off the helipad, it fell only a few feet onto the roof. On two other sides of the helipad, the helicopter would have gone off the edge of the building and fallen either 6 stories or 7 stories to the ground.] CHI86FA129

3. After loading a seriously burned patient in the helicopter, the pilot started the engine and lifted off from the hospital parking lot. Immediately after lift-off, he started forward translational flight. About 65 feet from the lift-off point, an advancing main rotor blade struck an unmarked lamppost. The helicopter then crashed in the parking lot, just beyond the lamppost. The pilot and one medical attendant were fatally injured; the other medical attendant was seriously injured. Reportedly, the patient did not sustain any additional discernible injury from the crash. **[This was a fatal accident.]** ATL85FA170

4. The helicopter crashed during a forced landing following a loss of engine power on takeoff. The commercial pilot and the two medical crewmembers received serious injuries, and the helicopter sustained substantial damage. The positioning flight was operating under Title 14 CFR Part 91 and was en route to pick up a patient for transport back to the medical center. Visual meteorological conditions prevailed and a company flight plan was filed. Witnesses reported that they heard a loud bang and saw black smoke coming from the helicopter shortly after it lifted off from the hospital helipad. According to local authorities, the helicopter descended into a parking lot, the main rotor struck a light pole, and the helicopter came to rest on its right side. **[This was not a fatal accident.]** FTW98LA239

5. The helicopter was being operated from a temporary landing zone (LZ) in a parking lot, while the hospital heliport was being resurfaced. As the pilot was preparing to takeoff at night to get a patient at another location, he noted personnel in the area of the LZ and advised the dispatcher of the lack of security. At that time, the weather (10 miles east at Houston Hobby Airport) was in part: 900 feet overcast, visibility 8 miles with light drizzle, wind from 040 degrees at 14 knots. The pilot began a vertical takeoff to climb over obstacles. He reported that after lift-off, the helicopter encountered turbulence and a venturi effect from wind blowing around the buildings. Also, he indicated that his visual cues were reduced as he was watching for people in the area of the LZ. At about that time, witnesses observed the helicopter drift backward. Subsequently, the tail rotor contacted the top of a garage, then the helicopter began an uncontrolled spin and crashed. The pilot and both medical crew members were seriously injured. **[This was not a fatal accident.]** FTW89FA078

COMMENTARY ON THE HOSPITAL HELIPORT ACCIDENT HISTORY

All of these accidents touch on issues of landing site design. A thorough search would probably turn up other such accidents as well. Circumstances similar to those that led to these accidents still exist at hospital heliports.

These accidents involve collisions with objects during ground maneuvers or during departure operations. Such accidents are among the more common helicopter accidents and the air ambulance industry has not been immune from such events.

In the mid-1980's, many air ambulance helicopter accidents occurred when the pilots were "scud running" (flying at very low altitudes to stay beneath the clouds in order to continue flying by visual reference to ground objects), often at night in marginal weather or worse. Much of the reduction of air ambulance helicopter accidents has been attributed to the reduction in the number of flights during bad weather. (Bear in mind the NTSB conclusion that "Weather-related accidents are the most common and the most serious type of accident experienced by EMS helicopters, and are also the most easily prevented.") As the air ambulance industry moves to implement global positioning system (GPS) instrument approaches at hospital heliports, the number of air ambulance flights in bad weather can be expected to increase. Since pilots will be flying IFR en route rather than scud running, one does not expect to see an abundance of en route accidents. Will we see an increase in the number of air ambulance helicopter accidents at hospitals? What steps should be taken to mitigate such accidents?

While any aviation accident is tragic, en route accidents seldom involve third party injuries or deaths. (In this context, third parties are anyone except aircraft passengers or crew members.) At a hospital, however, there are many third parties in close proximity. Thus, the risk of third party injury or death is much higher than with en route helicopter accidents. Any such accidents involving a third party could result in a public reaction similar to what occurred after the air ambulance accidents of the mid-1980's and the earlier Pan Am Heliport accident. What steps should be taken to mitigate the risk associated with such accidents?

BACKGROUND – FAA HOSPITAL HELIPORT DESIGN RECOMMENDATIONS

The FAA first included specific design recommendations for hospital heliports in the January 20, 1994 issue of the Heliport Design advisory circular, AC150/5390-2A. Prior to the addition of a specific chapter on hospital heliports in the 1994 advisory circular (AC), hospital heliports were considered as private heliports. Design guidance could be found in the private heliport chapter but it was limited and it did not specifically address hospital heliports.

During the late 1980's, the FAA and many in the helicopter industry became concerned with the high AIR AMBULANCE accident rate and the risk that a hospital heliport accident could have a widespread impact on the entire helicopter industry. Industry voiced this concern to the FAA in the discussions of the FAA/Industry Heliport Design Working Group (circa 1993). The FAA responded by drafting a hospital heliport chapter. After considerable negotiation with a working group that represented the AIR AMBULANCE industry, a modified version of this chapter was published in the 1994 version of the FAA Heliport Design AC. If the various sections of the 1994 Heliport design AC were listed from highest degree of safety to lowest degree of safety, the list would look as follows:

1. Transport Heliports
2. General Aviation Heliports
3. Hospital Heliports
4. Private Heliports

In the late 1990's, the FAA initiated a revision of the Heliport Design AC with the specific intention of deleting the chapter on private heliports and adopting certain safety enhancement recommendations. If the various sections of the 1999 revision to the 1994 Heliport Design AC were listed from highest degree of safety to lowest degree of safety, the list would look as follows:

1. Transport Heliports
2. General Aviation Heliports
3. Hospital Heliports

By looking at the AC in this manner, one sees a rather curious thing. Even after two attempts to "raise the bar" regarding the FAA recommendations for hospital heliport design standards, these standards still represent the lowest level of safety among the various chapters in this AC. Should steps be taken to bring the FAA hospital heliport design recommendations up to the same level of safety as GA heliports?

HOSPITAL HELIPORTS – ONE AREA OF PARTICULAR CONCERN

The hospital-to-hospital transfer of medical patients is usually "one way". That is, patient transfers are usually from a secondary or tertiary hospital to a primary hospital. This primary hospital might be a trauma center, a burn center, or some other specialty hospital. The hospital that is gaining a patient has an economic incentive to ensure that their hospital heliport is an adequate facility. With the advent of GPS heliport approach procedures, many of these primary hospitals (or their air ambulance helicopter operators) are starting to invest in GPS procedures. Economically this is a sensible business decision since the IFR approach capability increases the number of critical-care patients that the hospital can receive by decreasing the percentage of time that bad weather prevents their helicopters from operating. Medically this is also a good decision since it is likely to increase the number of lives saved with the higher level of care available at the primary hospital.

Consider the perspective, however, of the secondary or tertiary hospitals that are losing patients. They have an economic DIS-incentive to invest in their hospital heliports since a better heliport is likely to mean that more patients will use this means to leave the hospital. (Secondary and tertiary hospitals seldom have an air ambulance helicopter of their own. Any helicopters are generally "visiting" from another hospital facility.) Thus, if their hospital heliport does not meet FAA Heliport Design guidance, the hospital management is often unwilling to fund improvements. If larger visiting helicopters start using their hospital heliport (larger than the helicopter for which the heliport was designed), the hospital management is often unwilling to fund an expanded facility. If visiting helicopters start using their hospital heliport at night, the hospital management is often unwilling to pay for heliport lighting. If there is a need for an instrument approach procedure, the hospital management is often unwilling to pay for procedure development or any associated ground infrastructure expenses.

Who should pay for such hospital heliport safety improvements? The primary hospital receiving the patients is generally unwilling to pay for heliport improvements at other secondary or tertiary hospitals. The secondary or tertiary hospitals have an economic DIS-incentive to invest in their hospital heliports since it is a patient exit, not an entrance. The air ambulance helicopter operator has sometimes been willing to pay for the development of a private GPS procedure (which means that competitors probably can NOT use the same procedure). However, the air ambulance helicopter operator is seldom willing to pay for other hospital heliport improvements. Who should bear the cost of such expenses?

Over the years, there have been periodic discussions about paying for hospital heliport improvements via Airport Improvement Program (AIP) funding. Historically, FAA Order 5990.33, Field Formation of the National Plan for an Integrated Airport System (NPIAS), has specifically precluded any funding of hospital heliports. This prohibition has been based on the FAA's "interpretation of the will of Congress" that hospital heliports are private facilities since prior permission is required to land there. It is understood that public funds should not be spent on private facilities. However, while hospital heliports are private facilities, the public does receive a benefit from such facilities when they are used for the transportation of medical patients on an emergency of critical-care basis. Considering the continued importance of hospital heliports and the rapidly growing use of instrument approach/departure procedures at such sites, is it appropriate for the FAA to reconsider its "interpretation of the will of Congress"?

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HELIPORT DESIGN ISSUE PAPERS

OVERVIEW

Robert D. Smith, FAA, AND-710

October 22, 1998

The next five papers constitute a package of several related Heliport Design Issue Papers. Specifically, the titles of these issue papers are as follows:

Application of Transition Surfaces at Various Classes of Heliports

The Benefits of More Than One Approach/Departure Path

Vertical Dimensions of the Approach/Departure Surfaces

"Object Penetrations" of the Approach/Departure Surface and the Transition Surfaces Versus "Hazards to Air Navigation"

Marking and Lighting of Obstacles Adjacent to the Approach/Departure Path

Over the last several months, these issue papers have been in a state of evolution. A number of them have been modified more than once based on discussions within the Federal Aviation Administration (FAA) and discussions with representatives of the helicopter Industry.

Each of these papers is written as a stand-alone document. However, while the papers address these topics separately, there is a distinct relationship between these various topics. This relationship makes it difficult or impossible to discuss one of the topics without discussing several other topics at the same time. As a consequence, certain matters are discussed in more than one paper. While this is helpful to those interested in a particular issue, there is a certain amount of text and several of the figures that appear in more than one issue paper.

HELIPORT DESIGN ISSUE PAPER

APPLICATION OF TRANSITION SURFACES

AT VARIOUS CLASSES OF HELIPORTS

Robert D. Smith, FAA, AND-710

October 22, 1998

At a recent meeting, FAA spokesmen were surprised by an Industry interpretation of several paragraphs in the Heliport Design AC. In a discussion of minimum VFR heliport approach/departure airspace, an Industry spokesman argued that the transition surfaces DO NOT APPLY at private and hospital heliports. The spokesman pointed to the following paragraphs of AC150/5390-2A. (Wording differences are highlighted in **bold**. In this discussion, Industry did not mention the wording of the comparable paragraph in the Transport Heliport Chapter.)

> 17. APPROACH/TAKEOFF SURFACE. (Private Heliport Chapter)
>
> b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and should conform to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the FAR Part 77 **approach surface** which should be free of object penetrations.
>
> 27. APPROACH/TAKEOFF SURFACE. (Public GA Heliport Chapter)
>
> b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and conforms to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the FAR Part 77 heliport **approach and transitional** surfaces which must be free of hazards to air navigation. Paragraph 8 provides guidance on how to identify and mitigate hazards to air navigation.
>
> 58. APPROACH/TAKEOFF SURFACE. (Hospital Heliport Chapter)
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> b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and should conform to the dimensions of the FAR Part 77 heliport **approach surface**. Figure 1-6 illustrates the heliport approach surface which should be free of object penetrations.

An Industry spokesman pointed to the second sentence in each of these paragraphs. In the Public GA Heliport chapter, paragraph 27b specifically mentions the approach surface and the transitional surfaces. In the Private Heliport and the Hospital Heliport chapters, paragraphs 17b and 58b mention ONLY the approach surface. Thus, this Industry spokesman argued that the transitional surfaces are applicable at public GA heliports but NOT APPLICABLE at private heliports or hospital heliports.

Background. The wording of the 1988 Heliport Design AC clearly states that the transition surfaces apply at all heliports. The wording highlighted above was a new addition in the 1994 AC.

Discussion with Heliport Designers. We interviewed two heliport designers on this issue. Both have been in the business for over a decade. Both have designed and implemented numerous heliports, principally hospital heliports and other private heliports. Both argued that the transition surfaces ought to apply at all heliports.

Operational Considerations. Transitional surfaces are recommended as part of the clear airspace required for pilots to make safe approaches and departures. It takes a certain amount of clear airspace for a rotorcraft to land and takeoff safely. The amount of airspace required is not a function of heliport ownership.

Discussion with Retired FAA Personnel. We interviewed a retired FAA official who was intimately involved in both the 1988 and the 1994 revisions of the Heliport Design AC. He stated that he knew of no intent to declare that the transition surfaces only apply at public heliports. He viewed this inconsistency as an inadvertent result not consistent with the intent of either the FAA or the Working Group. Subsequently, this official's supervisor has stated that he agreed to the 1994 AC language understanding that the transition surfaces would not apply at private or hospital heliports. Quoting him on the rationale for his decision:

"The decision to drop any reference and/or requirement for transitional surfaces alongside the approach surfaces to private and hospital heliports hinged on the argument that approaches to these heliports will be visual. The approaches will be flown by pilots familiar with the approach and on a course and at airspeeds commensurate with the distance to obstacles alongside the approach."

This decision was made near the end of the several year efforts that resulted in the publication of the 1994 version of the Heliport Design AC. Pressure from Industry was forceful (This has consistently been the case during the last several decades). The rationale given above is inadequate to support the decision made.

On this issue, the wording of the 1994 Heliport Design AC is vague and ambiguous. It raises an issue as to whether other FAA offices clearly understood the intent of this vague wording in their review of the draft AC. A month after the AC was signed, AAS-100 distributed a memo clarifying the document's intent on this matter.

Recommendation.

Transition surfaces are part of the minimum recommended VFR approach/takeoff airspace and should be recommended at all heliports. The FAA should revise the wording of the proposed AC150/5390-2B to ensure that there is no ambiguity on this issue.

Rationale: As discussed in another Heliport Design Issue Paper, there are methods for addressing obstacles that penetrate the transition surfaces and deciding whether they constitute a hazard. Safety demands that such judgments be made rather than ignoring the transition surfaces entirely.

HELIPORT DESIGN ISSUE PAPER

THE BENEFITS OF MORE THAN ONE APPROACH/DEPARTURE PATH

Robert D. Smith, FAA, AND-710

October 22, 1998

In the draft revision of the Heliport Design advisory circular, AC150/5309-2B, the FAA has recommended that heliports should have more than one approach/departure path. While this paper also discusses some aspects of the shape and minimum size of the approach/departure airspace, the principal objective of this paper is to address the recommendation for more than one path. A further discussion of the shape and minimum size of the approach/departure airspace can be found in a separate Heliport Design Issue Paper.

FAA research has shown a need to modify the minimum recommended VFR heliport airspace. The proposed revision was defined in the draft Heliport Design advisory circular, AC150/5309-2B released to AHS/HAI in the spring of 1998. This revision has been controversial, particularly with regard to the horizontal dimensions. With regard to the vertical dimensions, however, Industry indicated (in the March 13, 1998 AHS/HAI letter) a willingness to consider a two-slope approach/departure path. FAA/Industry discussions have focused on considering the two-slope surfaces (see Table 4-1) developed by Transport Canada. (The three-slope surfaces developed by ICAO were considered and rejected by both FAA and Industry. They are confusing, contradictory, and overly complex. Neither the FAA nor Industry has suggested that the two-slope surfaces developed by some other aviation authority should be considered.)

FAA discussions with Transport Canada have indicated that their conclusions on the vertical dimensions of the minimum recommended VFR heliport airspace are remarkable similar to those of the FAA. Indeed, the dimensions of Table 4-1 were developed with a full consideration of the FAA research on this topic. Two of the four scenarios in Table 4-1 address heliports with **two or more** approach/departure paths. Two of the four scenarios in Table 4-1 address heliports with only **one** approach/departure path. The difference in the resulting recommendations lies in the slope of the first section of the approach/departure path. With heliports that have only **one** approach/departure path, Transport Canada regulations require that the first section be flatter than what is required at heliports that have **two** approach/departure paths. The rationale for this Transport Canada regulation is a matter of basic physics. At heliports that have only **one** approach/departure path, helicopter pilots will be forced, at times, to operate with a tail wind. Since helicopters do not perform as well with a tail wind, additional clear airspace is recommended.

After review of the dimensions of Table 4-1 and discussions with Transport Canada, the FAA proposed that Industry should consider the vertical dimensions of all four scenarios in Table 4-1. Industry rejected this proposal, arguing that it would be preferable to adopt something less complex. Industry specifically rejected the scenarios defined in columns (3) and (5) because they objected to the associated 65 m obstacle-free zones. FAA/Industry discussions quickly focused on the scenario of column (4). This scenario addresses heliports with **two** approach/departure surfaces and, in this respect, it is consistent with the proposed draft of AC150/5390-2B released to AHS/HAI in the spring of 1998. FAA and Industry reached a consensus on the dimensions shown in Figure 1.

Subsequently, Industry has proposed that AC150/5390-2B be modified to require only one approach/departure path at the vast majority of heliports in the nation and that Figure 1 should also apply in such cases. This is an unappealing proposal. Transport Canada's rationale for distinguishing between these two scenarios is sound; it is a simple matter of physics. Helicopter performance deteriorates in the presence of a tailwind. At a heliport with only one approach/departure path, the pilot will sometimes be forced to operate with a tail wind. To maintain an adequate safety margin under such a scenario, the additional airspace of Figure 2 is recommended. At the same time, the FAA recognizes that many existing heliports only have one approach/departure path and that a second path is impossible to obtain. How can the FAA

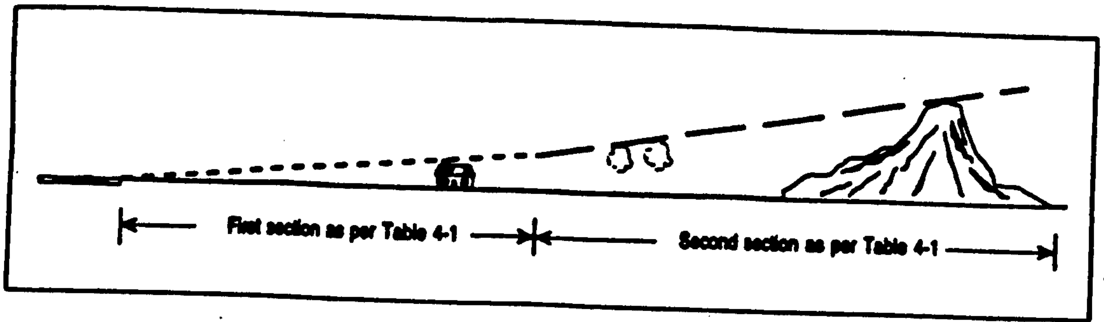


Figure 4-3. Take-off and approach surface for non-instrument heliport

Table 4-1. Dimensions and slopes of obstacle limitation surfaces - non-instrument FATOs

SURFACE and DIMENSIONS	NUMBER OF APPROACH/DEPARTURE PATHS AVAILABLE			
	Single		2 or more	
	FATO only	FATO + 65 m obstacle free zone	FATO only	FATO + 65 m obstacle free zone
(1)	(2)	(3)	(4)	(5)
APPROACH SURFACE and TAKE-OFF SURFACE:				
Length of inner edge	Width of safety area	Width of safety area	Width of safety area	Width of safety area
Location of inner edge	Safety area boundary	Safety area boundary	Safety area boundary	Safety area boundary
Divergence:				
Day use only	10%	10%	10%	10%
Night use	15%	15%	15%	15%
First section:				
Length	245 m	245 m	245 m	245 m
Slope	6% (1:16.6)	8% (1:12.5)	8% (1:12.5)	10% (1:10)
Second section:				
Length	830 m	830 m	830 m	830 m
Slope	16% (1:6.25)	16% (1:6.25)	16% (1:6.25)	16% (1:6.25)
Total length	1075 m	1075 m	1075 m	1075 m
TRANSITIONAL SURFACE:				
Slope	50% (1:2)	50% (1:2)	50% (1:2)	50% (1:2)
Height	45 m	45 m	45 m	45 m

encourage new facilities to be designed with two approach/departure paths without inadvertently encouraging state aviation authorities to close all current heliports with only one path?

Recommendation.

The revised Heliport Design AC should speak to the additional safety margin and the additional operational flexibility provided by more than one approach/departure path. The revised AC should recommend a minimum of two approach/departure paths for new facilities but should recognize that existing facilities should not be closed simply because they only have one path.

Rationale: At heliports with only **one** approach/departure path, helicopter pilots will sometimes be forced to operate with a tail wind. Since helicopters do not perform as well with a tail wind, there is an incumbent derogation in the associated safety margin and the risk of an accident is increased. Thus, the AC should recommend more than one approach/departure path while stating that existing heliports with only one path should not be closed on this basis alone.

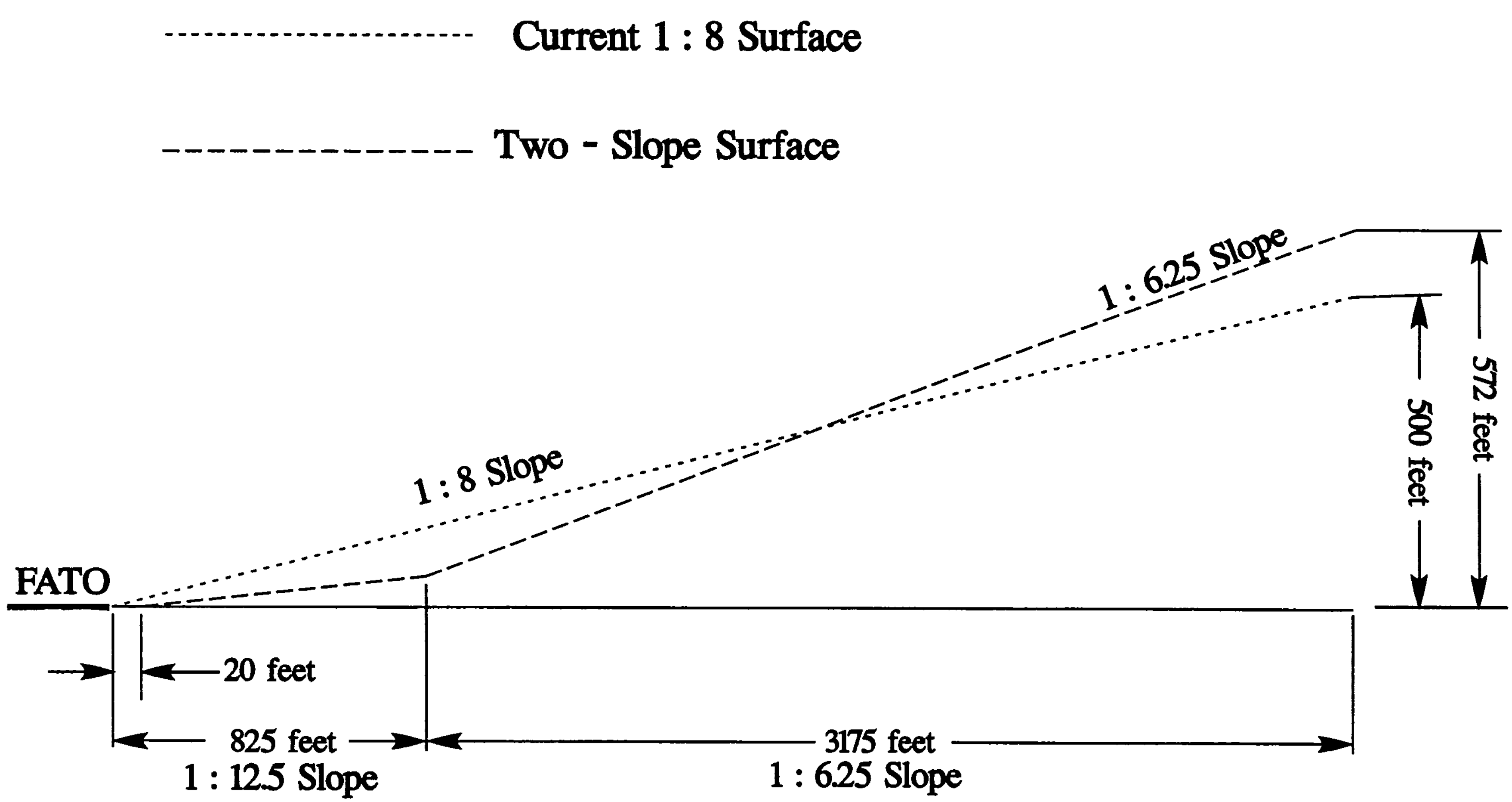


Figure 1. Comparison of the Current 1 : 8 Approach/Departure Surface and the Two - Slope Approach/Departure Surface (Two Approach/Departure Paths)

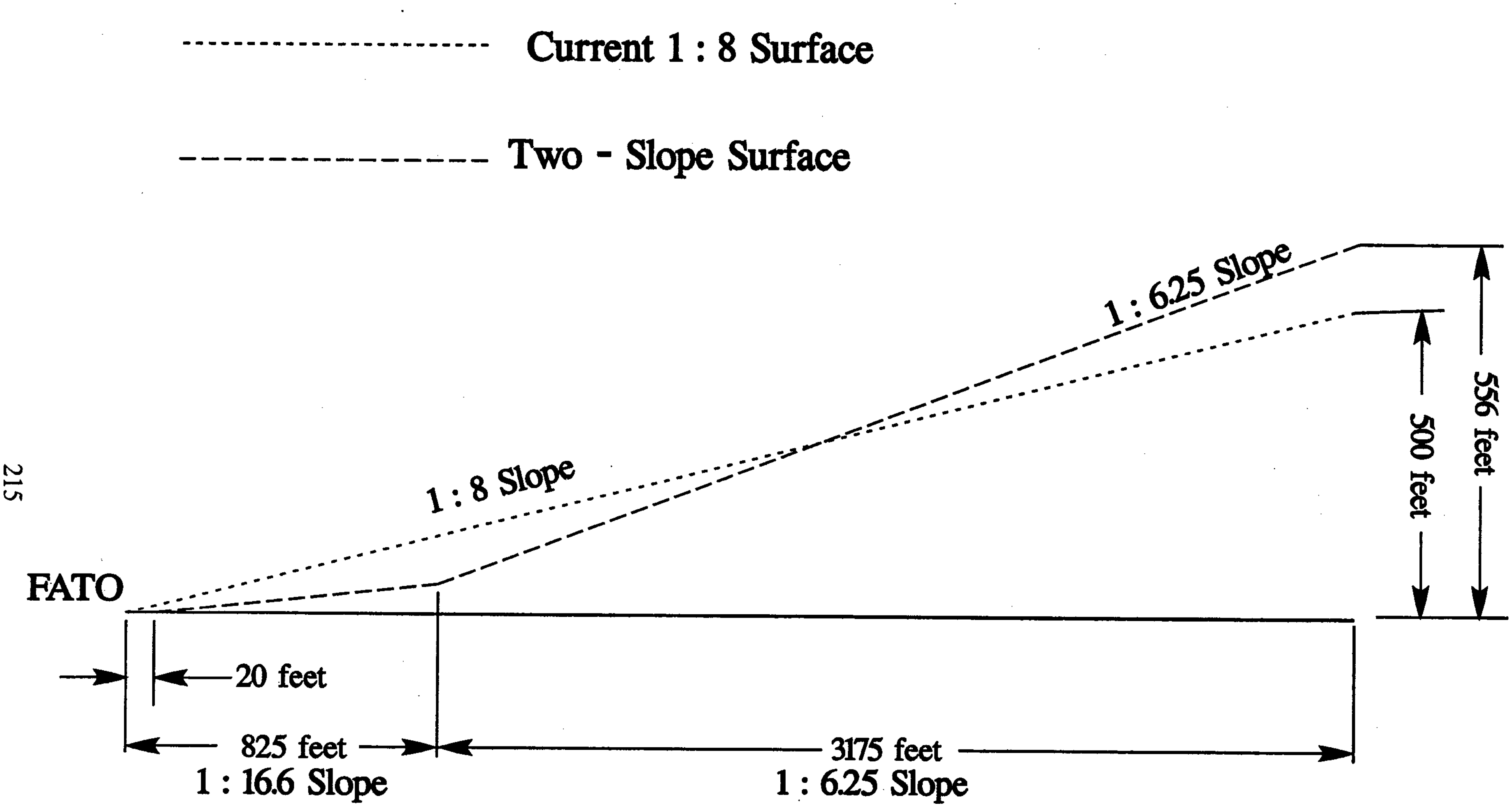


Figure 2. Comparison of the Current 1 : 8 Approach/Departure Surface and the Two - Slope Approach/Departure Surface (One Approach/Departure Path)

HELIPORT DESIGN ISSUE PAPER

VERTICAL DIMENSIONS OF THE APPROACH/DEPARTURE SURFACE

Robert D. Smith, FAA, AND-710

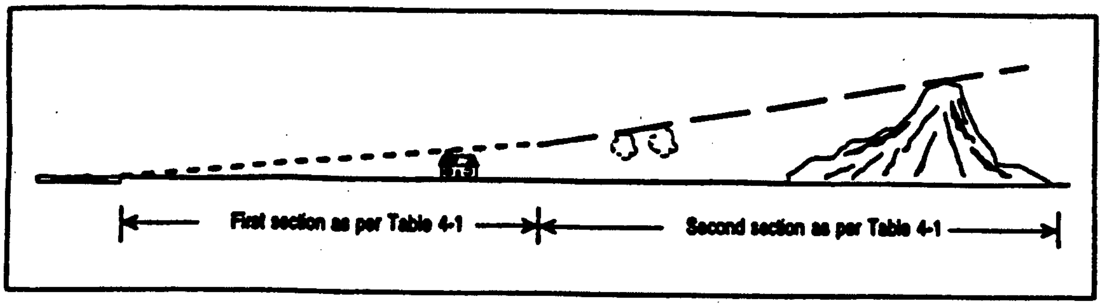
October 22, 1998

Modification of the Minimum Recommended VFR Heliport Approach/Departure Airspace. FAA research has shown a need to modify the minimum recommended VFR heliport airspace. The proposed revision was defined in the draft AC150/5309-2B. This revision has been controversial, particularly with regard to the horizontal dimensions. With regard to the vertical dimensions, however, Industry indicated (in the March 13, 1998 AHS/HAI letter) a willingness to consider a two-slope approach/departure path. FAA/Industry discussions have focused on considering the two-slope surfaces (see Table 4-1) developed by Transport Canada. (The three-slope surfaces developed by ICAO were considered and rejected by both FAA and Industry as being confusing, contradictory, and overly complex. Neither the FAA nor Industry has suggested that the two-slope surfaces developed by some other aviation authority should be considered.)

Discussions with Transport Canada have indicated that their conclusions on the vertical dimensions of the minimum recommended VFR heliport airspace are remarkable similar to those of the FAA. Indeed, the dimensions of Table 4-1 were developed with a full consideration of the FAA research on this topic. Two of the four scenarios in Table 4-1 address heliports with **two or more** approach/departure paths. Two of the four scenarios in Table 4-1 address heliports with only **one** approach/departure path. The difference in the resulting recommendations lies in the slope of the first section of the approach/departure path. With heliports that have only **one** approach/departure path, Transport Canada regulations require that the first section be flatter than what is required at heliports that have **two** approach/departure paths. The rationale for this Transport Canada regulation is a matter of basic physics. With heliports that have only **one** approach/departure path, helicopter pilots will be forced to make, under some wind conditions, to operate with a tail wind. Since helicopters do not perform as well with a tail wind, additional airspace is recommended.

After review of the dimensions of Table 4-1 and discussions with Transport Canada, the FAA proposed that Industry should consider the vertical dimensions of all four scenarios in Table 4-1. Industry rejected this proposal, arguing that it would be preferable to adopt something less complex. Industry specifically rejected the scenarios defined in columns (3) and (5) because they objected to the associated 65 m obstacle-free zones. FAA/Industry discussions quickly focused on the scenario of column (4). This scenario addresses the heliport with two approach/departure surfaces and, in this respect, it is consistent with the proposed draft of AC150/5390-2B released to AHS/HAI in the spring of 1998 (which recommends that heliports have more than one approach/departure path). FAA and Industry reached a consensus on the dimensions shown in Figure 1.

Subsequently, Industry has proposed that AC150/5390-2B be modified to require only one approach/departure path at the vast majority of heliports in the nation and that Figure 1 should also apply in such cases. This is an unappealing proposal. Transport Canada's rationale for distinguishing between these two scenarios is sound; it is a simple matter of physics. Helicopter performance deteriorates in the presence of a tailwind. At a heliport with only one approach/departure path, the pilot will sometimes be forced to operate with a tail wind. To maintain an adequate safety margin under such a scenario, the additional airspace of Figure 2 is recommended. At the same time, the FAA recognizes that many existing heliports only have one approach/departure path and that a second path is impossible to obtain. How can the FAA encourage new facilities to be designed with two approach/departure paths without inadvertently encouraging state aviation authorities to close all current heliports with only one path?



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Height	45 m	45 m	45 m	45 m

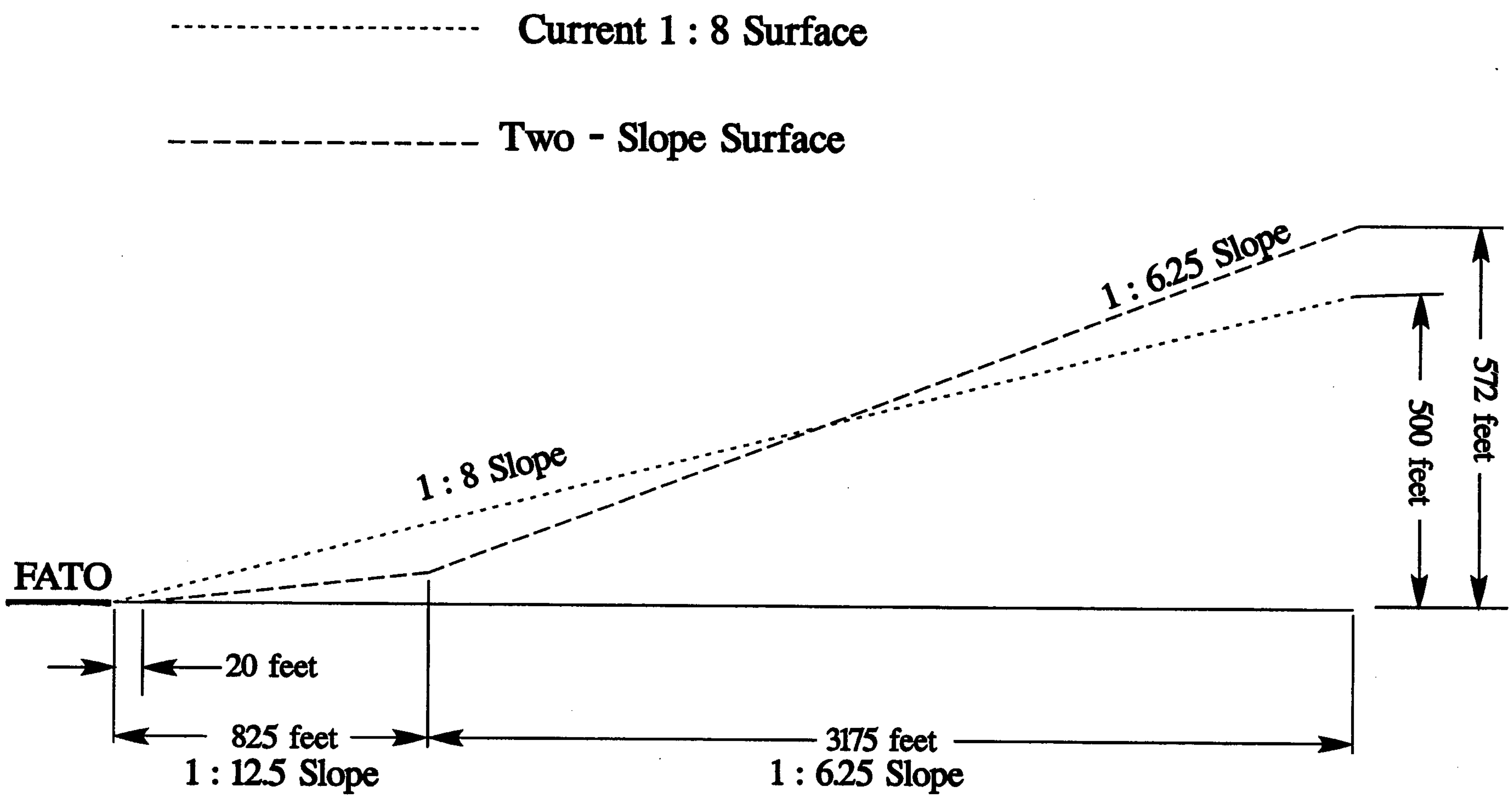
The FAA would strongly prefer to adopt both figures 1 and 2 as Transport Canada has done. Figure 1 would be for heliports with two approach/departure paths (separated by 150 degrees or more). Figure 2 would be for heliports with only approach/departure path. Unfortunately, we have been unable to reach a consensus on this point with Industry. As a compromise, the FAA and Industry have agreed to adopt figure 1. While this is less than ideal, it does provide an additional safety margin in comparison with the current Heliport Design AC recommendations. This additional airspace would also provide operators with additional operational flexibility.

Recommendation.

Adopt the two-slope approach/departure surface shown in figure 1.

Rationale: A number of power-limited helicopters in the US civil fleet can not stay above the current 8:1 slope on departure. They need this additional airspace for safe departure operations. Testing has shown that a significant percentage of pilots also dip below the 8:1 surface on approach. This behavior does not appear to be a function of available helicopter power. Thus, this additional airspace is needed on approach as well.

The FAA would strongly prefer to adopt both figures 1 and 2 as Transport Canada has done. Unfortunately, we have been unable to reach a consensus on this point with Industry. As a compromise, the FAA and Industry have agreed to adopt figure 1. While this is less than ideal, it does provide an additional safety margin in comparison with the current Heliport Design AC recommendations. This additional airspace would also provide operators with additional operational flexibility.



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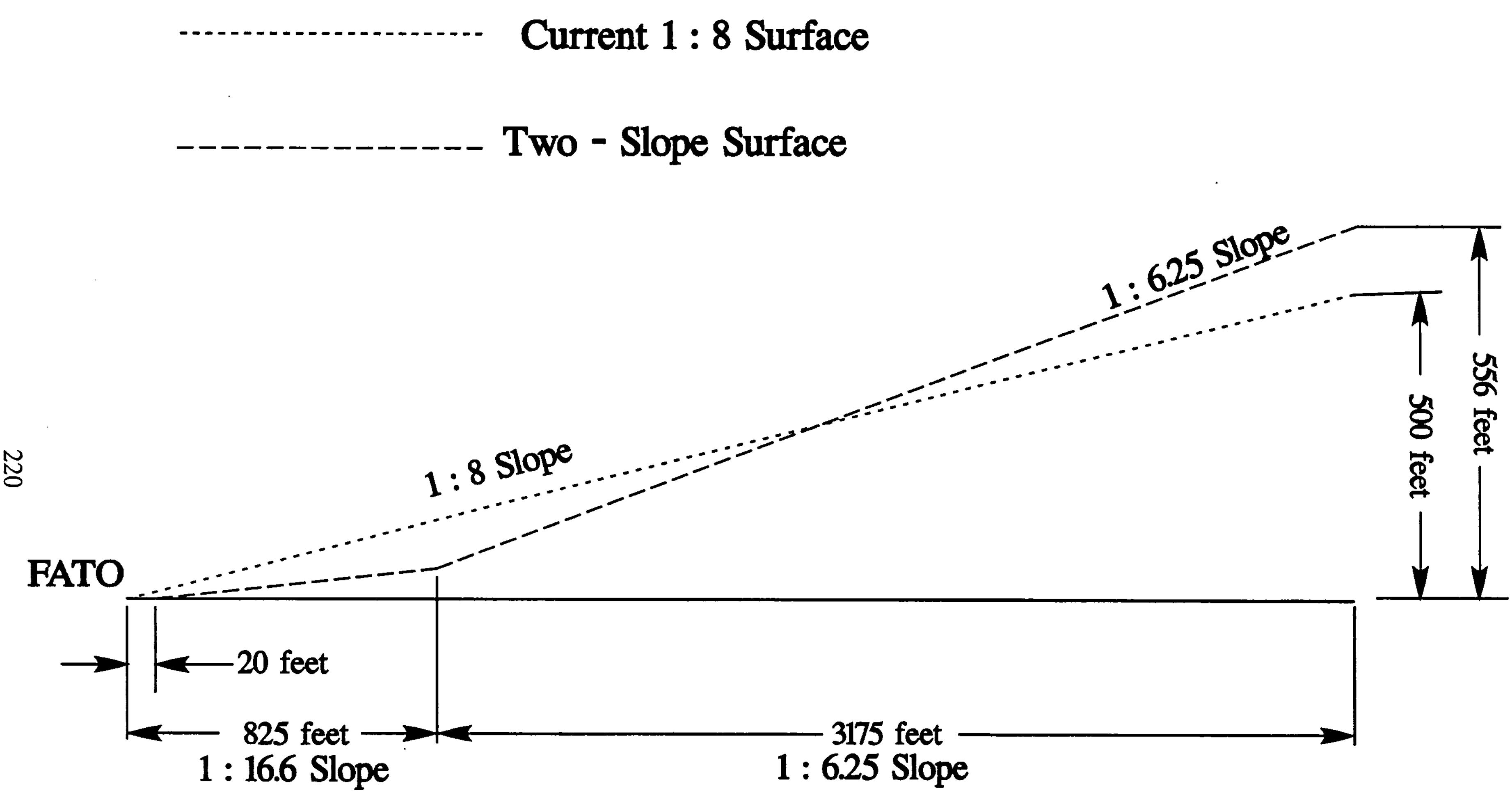

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HELIPORT DESIGN ISSUE PAPER
"OBJECT PENETRATIONS" OF THE APPROACH/DEPARTURE SURFACE AND THE TRANSITION SURFACES VERSUS "HAZARDS TO AIR NAVIGATION"

Robert D. Smith

October 22, 1998

Consider the wording of the Heliport Design Advisory Circular, AC 150/5390-2A. (Wording differences are highlighted in **bold.**)

17. APPROACH/TAKEOFF SURFACE. (Private Heliport Chapter)

b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and should conform to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the FAR Part 77 approach surface which **should be free of object penetrations.**

27. APPROACH/TAKEOFF SURFACE. (Public GA Heliport Chapter)

b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and conforms to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the FAR Part 77 heliport approach **and transitional** surfaces which **must be free of hazards to air navigation. Paragraph 8 provides guidance on how to identify and mitigate hazards to air navigation.**

42. APPROACH/TAKEOFF SURFACE. (Transport Heliport Chapter)

b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path. **The visual approach/takeoff surface** conforms to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the FAR Part 77 heliport approach **and transitional** surfaces which **must be free of hazards to air navigation. Paragraph 8 provides guidance on how to identify and mitigate hazards to air navigation. The approach/takeoff surface centered on the path aligned with the prevailing winds during instrument conditions should comply with the obstacle evaluation surfaces criteria cited in chapters 7 and 8.**

58. APPROACH/TAKEOFF SURFACE. (Hospital Heliport Chapter)

b. Approach/Takeoff Surface. An approach/takeoff surface is centered on each approach/takeoff path and should conform to the dimensions of the FAR Part 77 heliport approach surface. Figure 1-6 illustrates the heliport approach surface which **should be free of object penetrations.**

Should these surfaces be "free of object penetrations" or does marking and lighting any objects that penetrate these surfaces provide adequate safety, provided that they do not constitute a hazard?

Discussion with Heliport Designers. We interviewed two heliport designers on this issue. These individuals have been in this business for over a decade. Both have designed and implemented numerous heliports, principally hospital heliports and other private heliports. Both designers supported the idea that penetrations of the transition surfaces would not be a safety hazard if the penetrations did not exceed a few feet and if they were properly marked and, for nighttime operations, properly lit. Both designers argued that objects should NOT penetrate the 8:1 approach/departure surface.

Workload Considerations of Aeronautical Studies - Discussion with FAA Air Traffic (ATA-400, Airspace and Rules Division). In recent years, the number of FAA aeronautical studies of obstructions has increased dramatically. In 1997, the FAA conducted approximately 25,000 studies. In 1998, the number is expected to be around 30,000. The increase has largely been the result of actions by the Federal Communications Commission that have resulted in a dramatic increase in the number and height of radio

antennas. FAA personnel at the Regional level conduct these studies and the FAA has found it necessary to make adjustments and gear up for the increasing workload. As a consequence, if there should be a need to conduct a large number of FAA aeronautical studies of obstructions near heliports, the FAA could handle the additional workload.

Operational Considerations. Collisions with obstacles have been an operational concern for decades. The risk of collisions with wires is a particular concern because they are hard to see in time to take successful evasive action. Accident analysis shows that there have been many helicopter collisions with wires, both en route and on approach to or on departure from landing sites. Often such accidents are fatal. In recent years, the tragedy of numerous helicopter collisions with wires has led to an outcry from the helicopter Industry that such obstructions should be marked and lit. Since many wire strikes take place at less than 200 feet AGL, the number of markings being discussed could run into the millions and the associated cost could run into the billions of dollars. Understandably, neither the helicopter Industry nor those who install and maintain these wires wish to accept this financial burden.

Industry Position on Wire Markings. In considering Industry's statements and actions with regard to wire markings, there are several contradictions that are difficult to justify:

1. Marking wires to prevent en route accidents is a very expensive undertaking but many in the helicopter Industry argue for it passionately. Marking wires and other hard to see objects in the vicinity of heliport approach/departure paths would be considerably less expensive by comparison. The current Heliport Design AC (AC 150/5390-2A) defines specifically where such markings are recommended. In recent discussions, however, Industry spokesman have admitted that no great efforts have been made to mark all the wires near approach/departure paths as recommended by the FAA. There is a contradiction between Industry's words and their actions.

2. Many en route helicopter wire strikes take place in daytime VFR weather, circumstances under which the accidents could have been prevented by flying higher. Industry proposes wire markings instead. On heliport approaches and departures, flying low is an operational requirement. FAA testing has shown that pilots often fly below the 8:1 approach surface. Industry recognizes that this is the case. And yet Industry spokesmen also admit that no great efforts have been made to mark all the wires near heliport approach/departure paths as recommended by the current Heliport Design AC. There is a contradiction here.

3. At private and hospital heliports, the current Heliport Design AC recommends that the FAR Part 77 approach surface **should be free of object penetrations.** Some in Industry are now arguing that object penetrations of the approach surface are acceptable as long as they are marked and lighted. Some in Industry are also arguing that the transition surfaces should not apply at all. There is a contradiction here.

4. The FAA has concluded that the FAR 77 surfaces provided inadequate VFR heliport approach and departure airspace. A substantial increase in this airspace is proposed in the draft AC150/5390-2B. Industry has opposed this increase. As an alternative, Industry recommends that obstacles within this additional airspace be marked and lighted. The current Heliport Design AC recommends that obstacles within defined airspace adjacent to the approach and departure path should be marked and lighted. This defined airspace is much smaller than the proposed increase in VFR approach and departure airspace. And yet at a recent meeting, Industry proposed two significant reductions in the size of this defined airspace. There is a contradiction here.

Modification of the Minimum Recommended VFR Heliport Approach/Departure Airspace. FAA research has shown a need to modify the minimum recommended VFR heliport airspace. The proposed revision was defined in the draft AC150/5309-2B. This revision has been controversial, particularly with regard to the horizontal dimensions. With regard to the vertical dimensions, however, Industry indicated (in the March 13, 1998 AHS/HAI letter) a willingness to consider a two-slope approach/departure path. FAA/Industry discussions have focused on considering the two-slope surfaces (see Table 4-1) developed by

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Subsequently, Industry has proposed that AC150/5390-2B be modified to require only one approach/departure path at certain heliports and that Figure 1 should also apply in such cases. This is an unappealing proposal. Transport Canada's rationale for distinguishing between these two scenarios is sound; it is a simple matter of physics. Helicopter performance deteriorates in the presence of a tailwind. At a heliport with only one approach/departure path, the pilot will sometimes be forced to operate with a tail wind. To maintain an adequate safety margin under such a scenario, the additional airspace of Figure 2 is appropriate.

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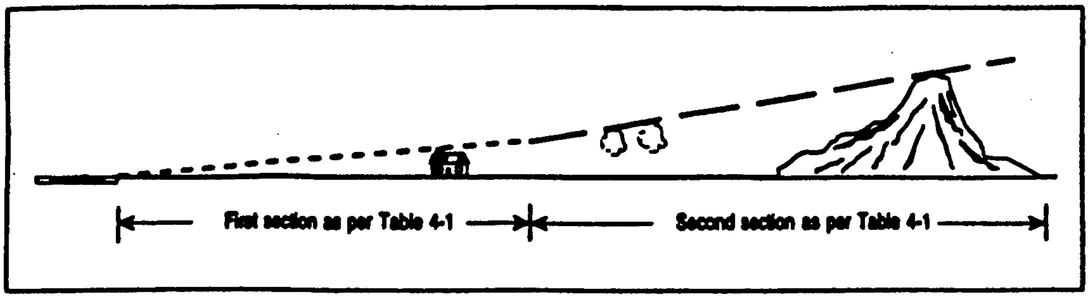

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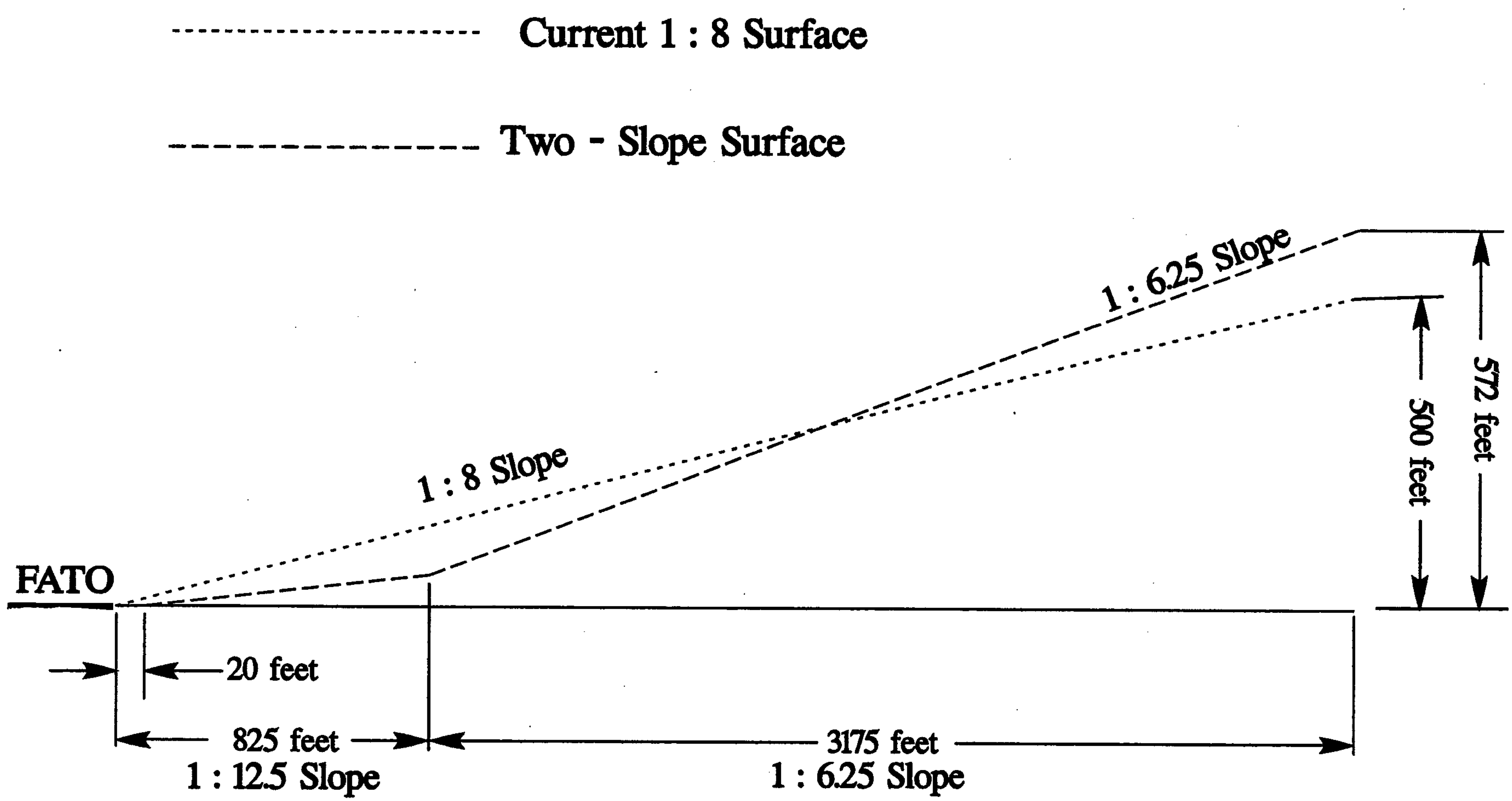

Figure 1. Comparison of the Current 1 : 8 Approach/Departure Surface and the Two - Slope Approach/Departure Surface (Two Approach/Departure Paths)

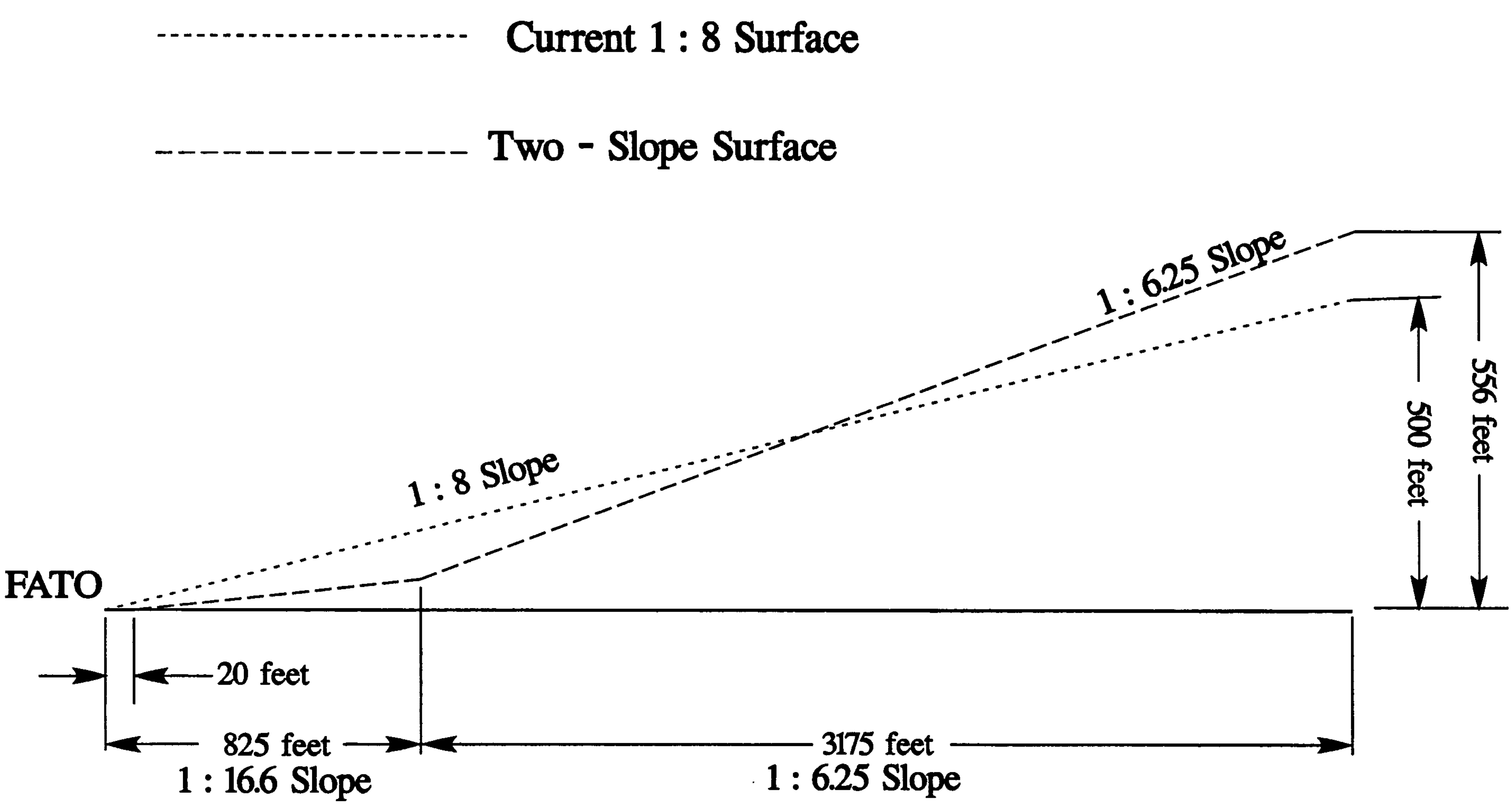

Figure 2. Comparison of the Current 1 : 8 Approach/Departure Surface and the Two - Slope Approach/Departure Surface (One Approach/Departure Path)

Recommendation.

In the paragraphs that discuss VFR approach/departure airspace, the FAA should modify the language of the revised AC150/5390-2B to make it consistent at ALL heliports. In each of these paragraphs, this should be done consistent with the follow recommendations:

a. The revised AC150/5390-2B should recommend that the heliport approach and transitional surfaces must be free of hazards to air navigation.

Rationale: With the increase in the minimum recommended VFR heliport approach/departure airspace (see Figures 1 and 2), a number of heliports that meet existing AC150/5390-2A may not meet the revised recommendations. A means is needed to allow existing heliports to continue operating if the obstacles in this airspace do not constitute a hazard. A means for doing this is already in place. The AC should clearly state that this process is appropriate at heliports and provide the appropriate references.

b. The revised AC150/5390-2B should reference the AC text addressing ways to mitigate the adverse effects of objects (paragraph 9 in the spring 1998 draft AC150/5390-2B).

Rationale: This paragraph speaks to how the FAA makes a determination on whether an obstacle constitutes a hazard and how this hazard should be mitigated.

c. In the revision of AC150/5390-2B, delete the last sentence of paragraph 33b (This is the same sentence shown above in paragraph 27b from AC150/5390-2A).

Rationale: This sentence addresses IFR airspace requirement in the midst of a paragraph on VFR airspace requirements. Of particular concern is the phrase "centered on the path aligned with the prevailing winds during instrument conditions." At many locations, the prevailing winds during IFR conditions will be significantly different than the winds during VMC conditions. Thus, the resulting sentence is ambiguous and confusing. While this issue may need to be addressed, it should be addressed in another part of the AC rather than in this paragraph.

HELIPORT DESIGN ISSUE PAPER
MARKING AND LIGHTING OF OBSTACLES ADJACENT TO THE APPROACH/DEPARTURE PATH

Robert D. Smith, FAA, AND-710
October 22, 1998

In the current Heliport Design advisory circular (AC150/5390-2A), paragraph 36 reads as follows:

> **36. SAFETY CONSIDERATIONS.** The following safety related features should be provided on an as needed basis:
>
> **a. Wire Marking and Lighting.** Unmarked electric and telephone wires in the heliports immediate area may be difficult to see. It is recommended that, where practical, wires located within 500 feet (150 m) of the FATO, as well as those within ½ mile (1 km) that are beneath and up to 100 feet (30 m) to the side of an approach/departure path be marked to make them more conspicuous. Figure 3-13 illustrates the area of concern. Guidance on marking and lighting objects is contained in AC 70/7460-1, Obstruction Marking and Lighting.

Background. The material of paragraph 36a was a new addition in the 1994 revision of the Heliport Design AC. This addition was made in recognition of the hazard of obstacles that are difficult to see in time to take evasive action successfully and in recognition of the inadequacy of the safety margin for VFR approach/departure airspace.

The impetus for this additional guidance came out of FAA research efforts that looked at VFR heliport airspace requirements from a variety of perspectives. Of specific interest are the following reports:

FAA/CT-TN87/40, Heliport Visual Approach and Departure Airspace Tests

FAA/CT-TN89/67, Analysis of Distributions of Visual Meteorological Conditions Heliport Data

FAA/RD-90/4, Heliport VFR Airspace Design Based on Helicopter Performance

FAA/RD-93/17, Safe Heliports Through Design and Planning – A Summary of FAA Research and Development

The specific dimensions of paragraph 36a were the result of negotiation between the FAA and Industry under the auspices of the FAA/Industry Heliport Design Working Group. Two points are of key interest. First, the ½ mile dimension is significantly smaller than what was recommended based on FAA research. Second, the 500 feet dimension is considerably larger than what was recommended.

Proposed Changes to Paragraph 36 a. For several reasons, it is appropriate to modify this guidance material. These reasons are discussed below.

Proposed Changes in Vertical Dimensions of the VFR Approach/Departure Airspace. FAA research has shown a need to modify the minimum recommended VFR airspace. The proposed revision was defined in the draft Heliport Design advisory circular AC150/5309-2B released to AHS/HAI in the spring of 1998. This revision has been controversial, particularly with regard to the horizontal dimensions. With regard to the vertical dimensions, however, Industry indicated (in the March 13, 1998 AHS/HAI letter) a willingness to consider a two-slope approach/departure path. FAA/Industry discussions have focused on considering the two-slope surfaces (see Table 4-1) developed by Transport Canada. (The three-slope surfaces developed by ICAO were considered and rejected by both FAA and Industry. They are confusing, contradictory, and overly complex. Neither the FAA nor Industry has suggested that the two-slope surfaces developed by some other aviation authority should be considered.)

FAA discussions with Transport Canada have indicated that their conclusions on the vertical dimensions of the minimum recommended VFR heliport airspace are remarkable similar to those of the FAA. Indeed, the dimensions of Table 4-1 were developed with a full consideration of the FAA research on this topic. Two of the four scenarios in Table 4-1 address heliports with **two or more** approach/departure paths. Two of the four scenarios in Table 4-1 address heliports with only **one** approach/departure path. The difference in the resulting recommendations lies in the slope of the first section of the approach/departure path. With heliports that have only **one** approach/departure path, Transport Canada regulations require that the first section be flatter than what is required at heliports that have **two** approach/departure paths. The rationale for this Transport Canada regulation is a matter of basic physics. At heliports that have only **one** approach/departure path, helicopter pilots will be forced, at times, to operate with a tail wind. Since helicopters do not perform as well with a tail wind, additional clear airspace is recommended.

After review of the dimensions of Table 4-1 and discussions with Transport Canada, the FAA proposed that Industry should consider the vertical dimensions of all four scenarios in Table 4-1. Industry rejected this proposal, arguing that it would be preferable to adopt something less complex. Industry specifically rejected the scenarios defined in columns (3) and (5) because they objected to the associated 65 m obstacle-free zones. Currently, FAA/Industry discussions are focusing on the scenario of columns (2) and (4).

Summary. In view of this proposed changes in the approach/departure surface, the FAA should modify the figures in the AC that define the dimensions of the airspace where marking and lighting of obstacles is recommended.

Rationale: This paragraph 36a material was added to the 1994 AC because the FAA and Industry saw the need to mark objects in close proximity to where the pilot actually flies. The two-slope approach and departure path is more representative of where the pilot actually flies than the 8:1 slope. Thus, it is appropriate to mark and light objects that are in close proximity to this two-slope surface.

Proposed Changes in Horizontal Dimensions of the VFR Approach/Departure Surface. The proposed revision of the minimum recommended VFR heliport approach/departure surface was defined in the draft AC150/5309-2B. However, at this point, it appears appropriate for the FAA to postpone plans to revise the horizontal dimensions of this surface until a future revision. The revision of figure 3-14 (from the spring 1998 draft of AC150/5390-2B), shown below in figures 1 and 2, is based on the assumption that the revision of AC150/5390-2B will contain no significant changes in the horizontal dimensions of the VFR heliport approach/departure surface.

Rationale: The horizontal dimensions of the VFR approach/departure surface are both complex and controversial and additional time is required to consider the issue.

One Change Recommended by Industry. Recently, Industry has proposed that paragraph 36a be revised as follows:

> "Unmarked wires in the heliports immediate area are difficult to see. It is recommended that, wires located within 100 feet (30 m) of the FATO, as well as those within ½ mile (1 km) that are beneath and up to 100 feet (30 m) to the side of an approach/departure surface, be marked to make them more conspicuous as illustrated in Figure (TBD). Guidance on marking and lighting objects is contained in AC 70/7460-1, Obstruction Marking and Lighting."

The principal change in this Industry recommendation is the decrease in the dimension around the FATO from 500 feet to 100 feet.

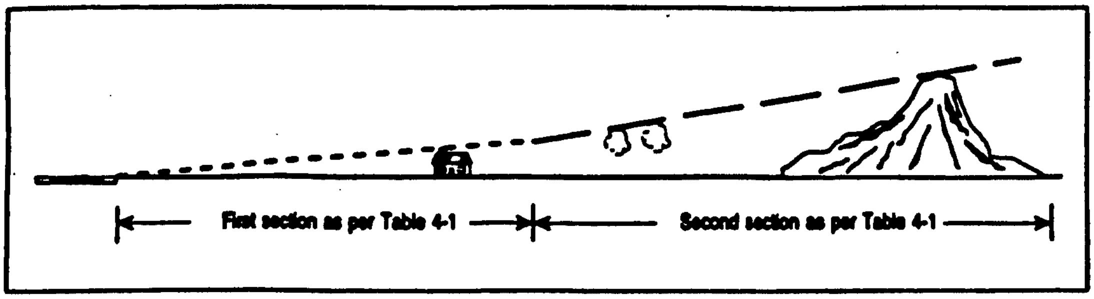

Figure 4-3. Take-off and approach surface for non-instrument heliport

Table 4-1. Dimensions and slopes of obstacle limitation surfaces - non-instrument FATOs

SURFACE and DIMENSIONS	NUMBER OF APPROACH/DEPARTURE PATHS AVAILABLE			
	Single		2 or more	
	FATO only	FATO + 65 m obstacle free zone	FATO only	FATO + 65 m obstacle free zone
(1)	(2)	(3)	(4)	(5)
APPROACH SURFACE and TAKE-OFF SURFACE:				
Length of inner edge	Width of safety area	Width of safety area	Width of safety area	Width of safety area
Location of inner edge	Safety area boundary	Safety area boundary	Safety area boundary	Safety area boundary
Divergence:				
Day use only	10%	10%	10%	10%
Night use	15%	15%	15%	15%
First section:				
Length	245 m	245 m	245 m	245 m
Slope	6% (1:16.6)	8% (1:12.5)	8% (1:12.5)	10% (1:10)
Second section:				
Length	830 m	830 m	830 m	830 m
Slope	16% (1:6.25)	16% (1:6.25)	16% (1:6.25)	16% (1:6.25)
Total length	1075 m	1075 m	1075 m	1075 m
TRANSITIONAL SURFACE:				
Slope	50% (1:2)	50% (1:2)	50% (1:2)	50% (1:2)
Height	45 m	45 m	45 m	45 m

Rationale for Accepting the Industry Proposal to Change from 500 feet to 100 feet: This recommendation is consistent with the FAA research recommendations of FAA/RD-93/17. However, this dimension of 100 feet should start at the edge of the Safety Zone rather than the edge of the FATO. (By starting at the edge of the Safety Zone, it enables the FAA to support a steeper slope than what would otherwise be acceptable (see next item).

A Change Recommended by the FAA. Both AC150/5390-2A and the proposed draft AC150/5309-2B recommend marking and lighting of obstacles near the heliport if they penetrate a 1:25 surface. This recommendation should be changed to a slope of 1:8 (This does not apply to obstacles under or adjacent to an approach/departure path.).

Rationale: Recommending the marking and lighting of all obstacles that penetrate a 1:25 surface is excessive. In our opinion, marking and lighting those obstacles that penetrate a 1:8 surface would provide adequate safety. (This does not apply to obstacles under or adjacent to an approach/departure path.)

Another Change Recommended by Industry. Various people in Industry have commented that the text of paragraph 36a (paragraph 27a in the draft AC150/5390-2B) is somewhat ambiguous. They have recommended that the text be modified to be clear and specific.

Rationale: Ambiguity should be avoided in an advisory circular. This is certainly an appropriate recommendation and the FAA should develop revised text accordingly.

Another Change Recommended by the FAA. A significant flaw in the guidance of paragraph 36a involves the ½ mile dimension. The original FAA research recommendation was that this dimension should be 4000 feet rather than ½ mile. This recommendation should be adopted.

Rationale: If there were a wire perpendicular to the approach/departure path, just beneath the approach/departure surface at 2700 feet from the FATO, the AC implies that there is no need for this wire to be marked or lighted. This is not the case. Bear in mind that, in many cases, the additional airspace of interest is more than 200 feet above ground level (AGL). Thus, there would be a compelling rationale to mark and light such objects even if the nearest airport or heliport was several miles away. However, in a case where there is rising terrain, a pilot might be on the approach/departure surface at 3800 feet from the heliport and still be significantly less than 200 feet AGL. A powerline crossing just beneath the approach/departure path would constitute a hazard even though it was less than 200 feet AGL. Thus, the AC should recommend such marking and lighting out to a distance of 4000 feet rather than ½ mile.

Obstacles of Concern. The principal obstacles of concern are wires since they are often hard to see, even in the best daylight weather, in time for a pilot to successfully take evasive action. It is not the FAA's intent to require that ALL objects in close proximity to approach/departure paths should be marked and lighted. Industry argues persuasively that pilots can readily see many obstacles during the day without specific markings and that many of these obstacles (e.g., high-rise buildings) already have lighting that allows them to be readily visible at night. Still, it must be said that there are other obstacles that can also be hard to see if not appropriately marked and lighted. These include objects such as antennas. The revision of the advisory circular guidance should make it clear that such hard-to-see objects should also be marked and lighted. This recommendation should be worded in a way that does not lead state and local officials to require marking and lighting of objects that are already clearly visible.

Summary Recommendations.

1. In the revised AC150/5390-2B, modify figures 2-14, 3-14, and 4-8 consistent with the attached Figures 1 and 2.

2. To avoid ambiguity in the revised AC150/5390-2B, the advisory circular text should discuss the various aspects of this airspace in greater detail, rather than simply referencing the figure as was done in AC150/5390-2A.

3. The principal obstacles of concern are wires since they are often hard to see, even in the best daylight weather, in time for a pilot to successfully take evasive action. Still, other obstacles, such as antennas, can also be hard to see if not appropriately marked and lighted. The revision of the advisory circular guidance should make it clear that such hard-to-see objects should also be marked and lighted. This recommendation should be worded in a way that does not lead state and local officials to require marking and lighting of objects that are already clearly visible.

4. Industry has regularly proclaimed their willingness to support marking and lighting of obstacles when required for safety reasons. Perhaps with a more rigorous educational effort by Industry and the FAA on the need for such markings, better marking will be achieved in the vicinity of heliports and in the vicinity of heliport approach/departure paths.

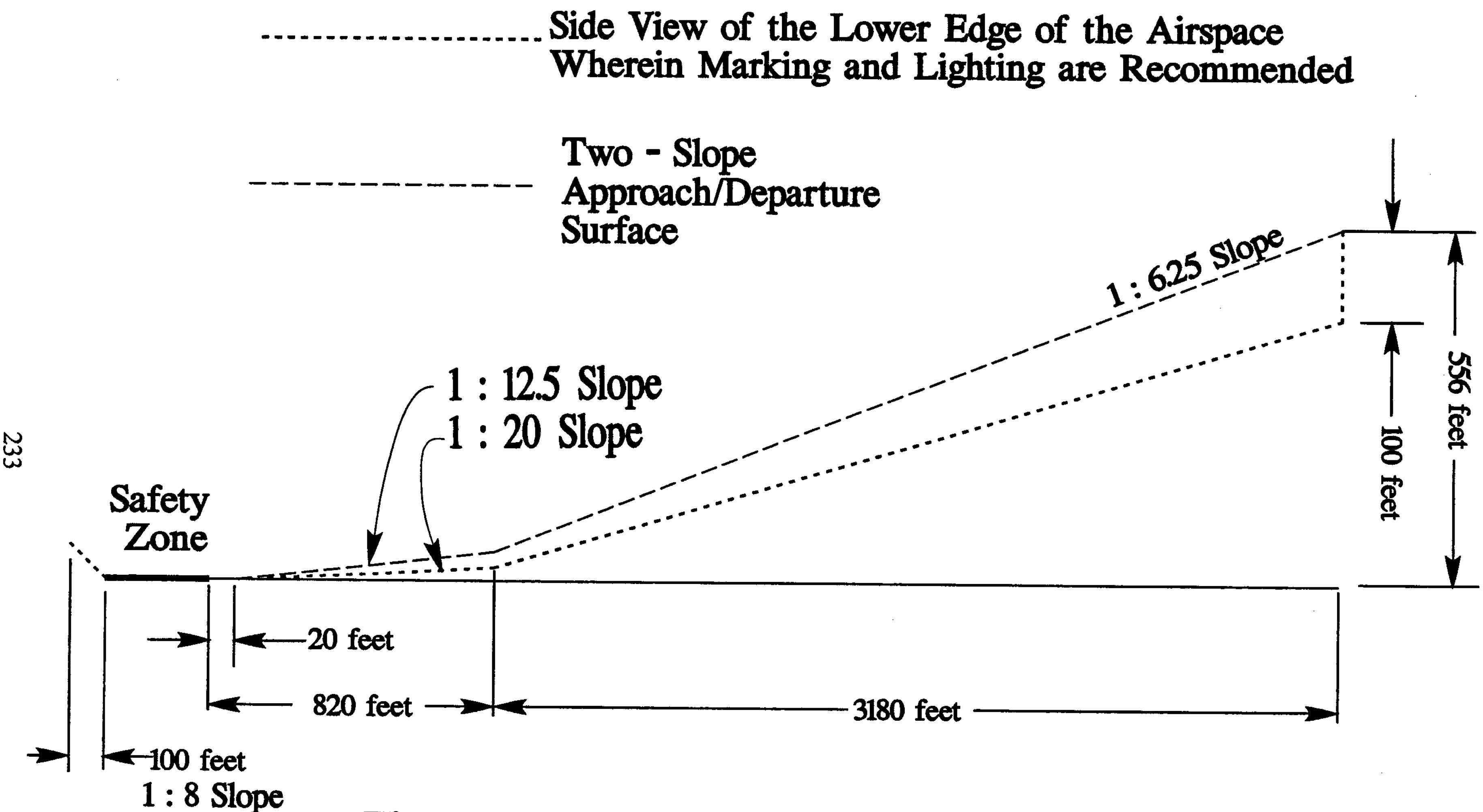

Figure 1. Side View of the Airspace Wherein Marking and Lighting are Recommended

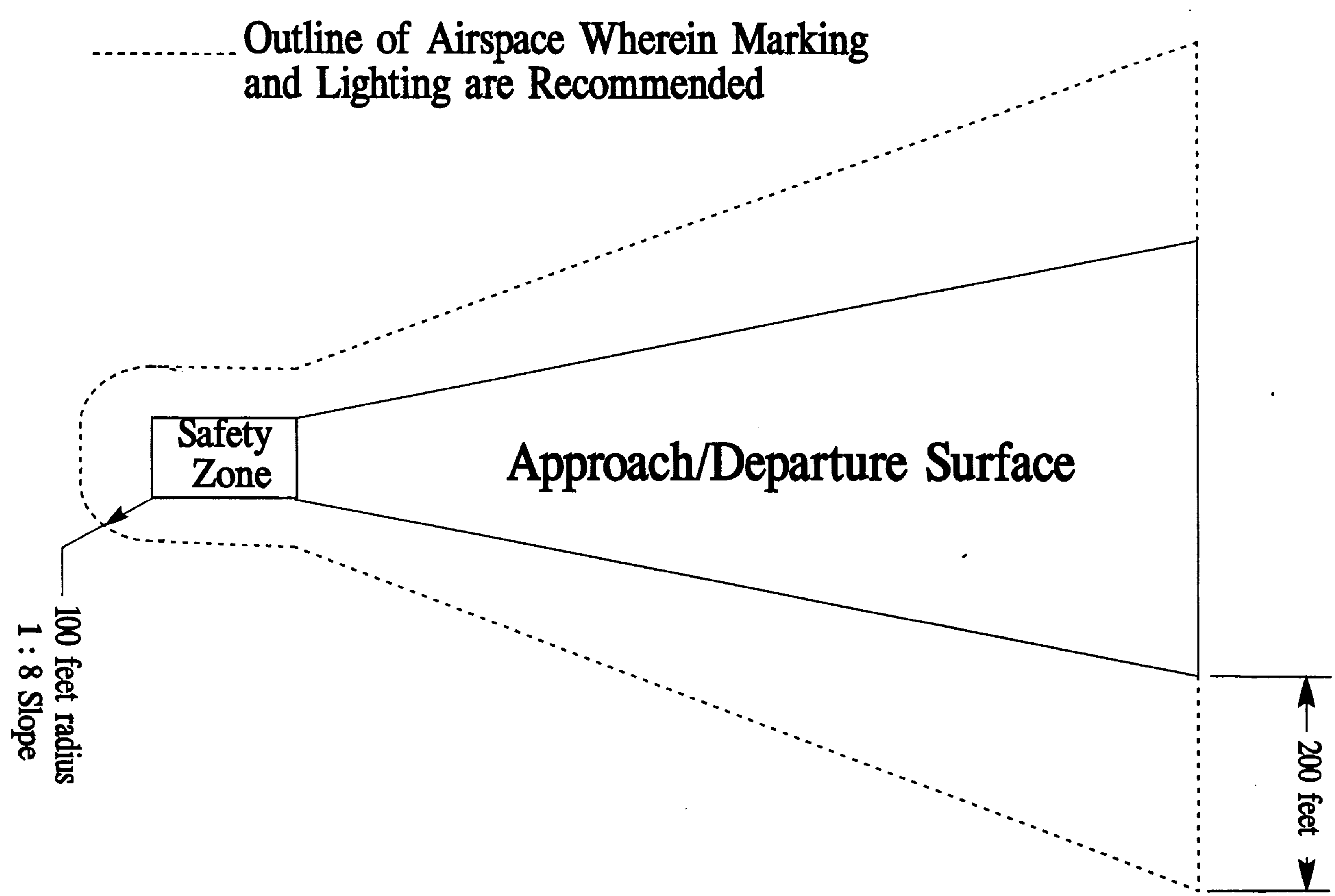

Figure 2. Top View of the Airspace Wherein Marking and Lighting are Recommended

ENTER AT OWN RISK

The height-velocity diagram may be only advisory in nature, but the pilot who does not treat it with due respect is flirting with disaster.

By Keith Engelsman
Rotorcraft Pilot

All helicopter flight manuals contain a similar warning. It is known by many names: Limiting height-speed envelope; avoid area; and dead man's curve are just a few. The generally accepted term is height-velocity (HV) diagram, which in itself does not suggest anything hazardous. The fine print that accompanies the HV diagram is normally a mild admonition to "avoid operation in the shaded area." A typical HV diagram is shown in Figure 1.

A casual study of the diagram does not indicate the potential dangers of ignoring the advice given. After all, it is only advisory, hence it's usual placement in the performance section of the flight manual. For some aircraft types the diagram appears in the limitation section; but this is not strictly correct, as it is not a limitation on, or prohibited area of operations.

Manufacturers are required to produce HV diagrams as part of the aircraft certification process. The actual regulation states among other requirements, "If there is any combination of height and forward speed (including hover) under which a safe landing cannot be made under the applicable power failure condition … a limiting height-speed envelope must be established (including all pertinent information) for that condition …."

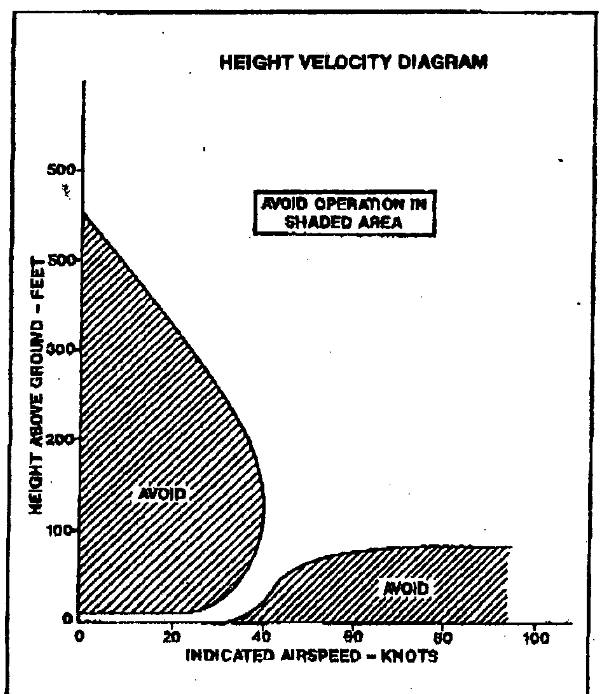

Figure 1

The applicable power condition referred to means complete and sudden power loss on one engine with the remaining engine(s), if you have any, operating at maximum power. The regulation also requires the envelope to cover all weights up to maximum takeoff weight at altitudes up to at least 7,000 feet.

Development of an HV diagram is a very high risk and expensive operation. The manufacturer will wish to produce the smallest "avoid area" possible, which in turn will require test flights to be the very edge of the safe landing envelope. Unsafe landing will, by definition, result in some damage to the aircraft, and possibly to the crew and passengers also. For these reasons, HV testing is normally left until the end of the certification program, the oldest development aircraft is used, and there is a certain amount of "short straw drawing" in the test pilots office.

Before commencing HV testing, the test pilot will become totally familiar with the autorotational characteristics of the aircraft. This will include rotor decay rates, handling qualities during transition from powered to autorotative flight and optimum flare heights, attitudes and rates. The test aircraft will be instrumented to record critical parameters, notably vertical and longitudinal accelerations, and loaded to the correct weight. Support personnel, including fire and rescue services, will be briefed on their part of the tests.

The flying to develop the HV diagram will involve dozens, and even hundreds, of data points. The aircraft will be flown to its absolute limits, with respect to vertical and horizontal accelerations in an attempt establish the smallest possible "unsafe" areas. Occasionally, limits will be exceeded and there will be a pause in the program while the aircraft is repaired or replaced.

At the end of the program, the certification authority will require the manufacturer to prove the HV diagram. This process involves spot checks of certain points along the edge of the avoid areas. It is carried out by an experienced test pilot after a comprehensive familiarization with the aircraft and its autorotational characteristics.

The net result, as shown in the flight manual, is the product of extensive testing and checking. But what does it mean for the average helicopter pilot?

First and foremost is the fact that, if you have an engine failure while operating in the avoid area, you will damage the aircraft in the ensuing landing. The extent of damage will depend on how far over the line you are and may result in injury to you and your passengers. For example, engine failure during a high hover taxi ("high" means greater than five feet in most machines) will damage the landing gear (or skids) but hopefully not much else, always assuming you eliminate yaw and drift before touchdown. More dramatic is an engine failure while hovering at 100 feet.

Another feature of HV diagrams is that unlike other performance data in the flight manual, there is no margin for error. They have been developed according to the capabilities of someone who is probably the best pilot in that particular machine. The chances of anyone other than a test pilot doing better are about the same as winning the lottery. Hence, in all probability, an engine failure that may be in the "safe" area, but close to the line, will probably result in an accident. This has been proven on several occasions by overzealous instructors seeking a more demanding emergency simulation for their students.

There are a few simple rules for dealing with the HV diagram, however, that can help all helicopter pilots avoid disaster:

Rule 1. If at all possible, *do not fly in the avoid areas:* keep your hover and air taxi height as low as possible (three to four feet is normally ample). Consider whether it is really necessary to hover at 200 feet to take that picture. Think about going higher or adding airspeed. Avoid low passes because they allow no room for error.

Rule 2. Do not take liberties with avoid area boundaries. You would be amazed if you knew how little margin there is before the bottom drops out of your world. Your insurance company will not thank you for failed attempts to advance this area of aviation research.

Rule 3. If you must operate in the avoid area, give yourself the best chance of minimizing injury in the event of an engine failure. Seat in good condition to absorb impact forces? Harness tight and secure? How about a helmet on your next sling load job?

As with many other aspects of aviation operations, misconceptions and misleading advice abound about the HV diagram. Here are a few to bear in mind:

"It only applies to maximum weight operations" – not so. Some parts of the avoid areas are defined by pilot reaction irrespective of weight. The problem is that you do not know where they are and what margin, if any, exists for reduced vertical velocities at lighter weights in other areas. See Rule 2 before contemplating flight in these areas at any weight.

"High hovers and air-taxiing are safe in strong wind" – only true in very strong (greater than 40 knots in the diagram) winds and even then there is a complication. Remember that the HV diagram relates to indicate air speed, but when the engine stops at 100 feet and 40 knots indicated, ground speed becomes a major consideration. Construction of the HV diagram involves use of flare effects wherever possible. If airspeed equals wind speed then that flare effect is not available – unless you wish to touchdown going backwards.

"The high hover limit point (450 feet in the diagram) is the minimum height I should fly downwind" – not so. The HV diagram only holds true for a landing in the direction of flight following power failure. Minimum recommended downwind height is dictated by the autorotational performance and handling of the particular aircraft type. There is no direct correlation between the two issues.

The HV diagram has been provided to warn pilots of a potential danger. If you must operate within the area, such as during sling load operations, then give yourself the best chance of surviving the inevitable crash landing if the engine stops. Keep in mind that you enter the avoid area at your own risk.

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CREW CONFUSION LEADS TO TROUBLE

Lack of teamwork results in an uncoordinated response to an in-flight emergency.

The mission had been to fly to a field about 55 minutes away, pick up passengers and return to home base. While the pilot planned the flight, the copilot preflights the aircraft. A fuel sample was not taken and the aircraft was overdue for an engine run up and daily inspection. Although required, there was no pre-mission coordination between the crew members concerning duties in the event of an emergency.

The first leg of the flight was planned and except for a slight fluctuation in EGT, aircraft performance was satisfactory. The copilot, apparently to reduce fuel consumption, decreased engine speed to between 6,400 and 6,500 rpm. The helicopter was refueled at the passenger pickup point. The return flight was delayed more than two hours while the crew awaited arrival of the passengers. When the passengers finally arrived, the departure was made without a passenger briefing.

A VFR flight plan was filed. Weather at the destination was 800 feet overcast with 10 miles visibility. When the aircraft was 14 miles east of the destination, a ground-controlled approach was requested. The aircraft was 10 miles out in level flight at 4,000 feet when the pilot took the controls and began to fly on instruments. The ground-controlled approach was initiated and the aircraft entered a cloud layer at 1,800 feet. At this point, a prelanding check was made, and the landing light was extended but not turned on.

As the aircraft cleared the bottom of the cloud layer, the rpm warning system activated; N_2 rpm and rotor rpm dropped to 6,000 and 300 respectively (needles joined). The pilot lowered the collective without rolling the throttle off and began a left run toward a forced landing area. He then made a Mayday call and decided to try to increase engine rpm using the increase/decrease switch. Simultaneously, the copilot moved the fuel control governor switch to the emergency position. The resulting engine overspeed was in excess of 7,000 rpm, and the rotor overspeed was in excess of 400 rpm.

The aircraft responded with an immediate nose-up attitude and right yaw. The pilot increased collective pitch and retarded the throttle to decrease engine and rotor rpm. Without waiting for acknowledgement from the pilot, the copilot returned the governor switch to the automatic position. Engine and rotor rpm decreased and stabilized at 6,000 rpm and 300 rpm, respectively, with the collective full down and throttle full on.

At a height of 300 to 400 feet, the helicopter's airspeed was 40 knots and decreasing. The pilot lowered the nose of the aircraft and the airspeed stabilized at 40 knots. Approximately 20 to 30 feet above the ground, the pilot decelerated but did not apply power until ground contact was made. The aircraft approached the ground in a nose-high attitude with about 20 knots of forward airspeed. Touchdown was hard. Collective was increased and the aircraft became airborne again, and then pitched forward. The main rotor blades hit the ground three times and the transmission was displaced. The aircraft came to rest in an upright position, substantially damaged.

The 28-year-old pilot had accumulated almost 800 rotary wing flight hours. More than 700 of these were Bell 212s. The 22-year-old copilot had almost 300 rotary wing flight hours, with more than 200 in the Bell 212. The performance of both pilots was satisfactory during the post-accident flight evaluations. However, both displayed weaknesses in the knowledge of emergency procedures, use of the checklist and the performance of autorotation. Neither knew the correct procedure for manual operation of the throttle with the governor switch.

During the ill-fated flight, the pilot had permitted the copilot to reduce N_2 rpm to considerably less than 6,600 rpm, supposedly to conserve fuel. The aircraft had been refueled before start for the return leg of the mission, but the estimated time en route was only one hour. The need for fuel/range management, therefore, was irrelevant to safe accomplishment of the mission. A further reduction of N_2 may have inadvertently

occurred later in the flight, causing the rpm warning system to activate. There was no evidence to confirm a materiel malfunction.

An approach with lower than appropriate power was made because the pilot and copilot incorrectly assessed a low engine/rotor rpm indication as a low-side governor failure, and failed to respond to the suspected emergency correctly. Following the onset of the emergency, the pilot began to remedy the condition by increasing N_2 rpm. The copilot placed the governor switch in the emergency position while the throttle was in the full-on position without telling the pilot. When the pilot tried to compensate for the resulting engine/rotor overspeed by adding collective and rolling off the throttle, the copilot reversed his earlier action and returned the governor switch to the automatic position, causing further confusion.

The cumulative effect of these actions may have overloaded the pilot to such a degree that he was unable to complete the approach and landing without damaging the aircraft. The pilot initiated the deceleration phase of the approach at too low an altitude (about 25 feet) to fully realize an appreciable reduction in forward speed and sink rate before touchdown was imminent. As a result, he was late in applying control inputs necessary to arrest the rate of decent and achieve a near-level attitude on landing.

Although the copilot cannot be faulted for misinterpreting a probable reduced N_2 condition as a low-side governor failure, he should not have cycled the governor switch into and out of the emergency position without the pilot's knowledge. The pilot did not brief the copilot before the flight regarding duties and responsibilities in the event of an emergency. Also, when the pilot began to remedy what he though was reduced N_2 condition, he did not coordinate his actions with the copilot.

The operator had an excellent training program in writing. However, it was not being enforced. Training in the use of appropriate publications, weather, emergency procedures was not provided on a regular basis. Stress and its relationship to crew members performance, as well as the types of errors that lead to creation of a high stress situation, should be discussed at safety meetings.

Managers must ensure the personnel are able to perform assigned jobs. Less experienced pilots must be continually monitored, evaluated and trained as necessary to ensure they are capable of coping with inflight emergencies. Aviator judgment should be evaluated as an area of special interest during standardization evaluations and training flights. Managers should emphasize to their pilots the importance of crew briefings prior to flight, proper crew coordination, and aviation professionalism in general.

[This article was originally published in Business Aviation Safety. It was later reprinted in the Flight Safety Foundation publication "Helicopter Safety" (Vol. 16, No. 5, Sept/Oct 1990).]

THE PHILOSOPHY AND REALITIES OF AUTOROTATIONS

Like the power-off glide in a fixed-wing aircraft, the autorotation in a helicopter must be used properly if it is to be a successful safety maneuver.

By
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Aviation Consultant

In all helicopter flying, there is no single event that has a greater impact on safety than the autorotation maneuver. The mere mention of the word "autorotation" at any gathering of helicopter pilots, especially flight instructors, will guarantee a long and lively discussion. There are many misconceptions about autorotations and they contribute to the accident rate when an autorotation precedes a helicopter landing accident. One approach to a discussion of autorotations is to look at the subject from three views: first, the philosophy of the subject; second, the reality of the circumstances that require autorotations; and third, the execution of the maneuver.

An important step in understanding the philosophy of a subject is to know its history, because it is only by studying a long period of time that we can recognize a trend in events and acquire a better understanding of why we do some maneuvers in a certain manner. The airplane preceded the helicopter by about 40 years. If we consider today's public attitudes regarding helicopters, their regulation, training concepts and the evolution of their designs and uses, there is an amazing parallel between airplane history and helicopter – offset by 40 years. We can use this parallel of history to predict some things about the helicopter.

In the early years of airplane flight, the fear of engine failure, or that the airplane might have structural problems during flight was very strong. If either of these events took place, the pilot's ability to get the airplane safely on the ground quickly was important. The time it took to get the airplane on the ground was directly in proportion to the altitude at which the airplane was being flown. It is therefore logical that all early flights were flown at low altitudes, often at less than 500 feet above the ground (AGL).

At these low altitudes, the pilot did not always have the time to turn the aircraft into the wind prior to making an emergency landing. Although landing into the wind was the best thing to do, very seldom were flights made on windy days anyway. With stalling speeds of 20 – 30 miles per hour and low wind speeds, a downwind landing into trees or a rough field may have almost always resulted in a loss of the aircraft, but the pilot and any passengers were usually not severely injured.

The first airplane fatality occurred on September 17, 1908, almost five years after the first flights by the Wright Brothers in 1903. U.S. Army Lt. Thomas Selfridge was killed while flying as a passenger on the "Wright Flyer" after a structural failure of the propeller. Selfridge had designed, built and flown his own airplane, the "Red Wing" in March of that same year.

As time went on, in response to public demand, laws were written that required airplanes to fly higher and to be built safer (according to the justification of the first U.S. aviation laws as stated in the preamble of the Civil Aeronautics Act of 1926). Airplanes and their engines became more reliable and were being designed to fly faster – which meant that the speeds at which these airplanes would stall were increasing. By then, always landing into the wind became more important. This meant that pilots could fly at altitudes that would allow them to turn into the wind in the event of an engine failure (structural failure of the aircraft was becoming less common). For this reason, airplane pilots changed their habits and increased their normal flying altitudes to 1,000 feet AGL or higher. It was not until modern cross country flights began that even higher cruising altitudes became the norm.

The helicopter industry seems to be fascinated with 500-feet AGL cruising altitudes. Looking back on history, possibly related to the rotorcraft's hovering capability, all flights were made close to the ground. The first recorded major helicopter mishap in the United States was December 9, 1939, some 90 days after

Igor Sikorsky's first flights. This is when the Sikorsky RX-4 rolled over during a test flight. Since these flights were made under tethered conditions, the action of the restraining cable may have caused the accident. (Sikorsky's first untethered flights in a helicopter were not made until May 1940.)

Mirroring the initial years of airplanes, in the early years of the helicopter experiments there were many material failures. Even Bell Aircraft Corp., which began serious helicopter flights almost 10 years after Sikorsky, suffered accidents due to material failures. The first major accident for Bell was in its Model 47. A main rotor hub broke on April 5, 1946, which resulted in serious injuries to the test pilot. Some engine failures did occur, usually because the helicopter ran out of fuel, as was the case in the world's first real autorotation during the Sikorsky flight test program. Most helicopter manufacturers were using modified airplane engines, so mechanical engine failures were reasonably rare.

One good thing about helicopter test flying is that much of it can be done in a hovering mode, or at least at a fairly low forward speed and at low altitudes. As helicopter structures became more reliable, the major fears during test flights were vibration and loss of aerodynamic control. More than once, a test pilot, accustomed to flying at 50 feet or lower, would perceive that it took an eternity to get back on the ground if trouble developed while flying at 500 feet AGL and it took as much as 15 or 20 seconds before landing.

However, most pilots flying today's helicopters are not acting as test pilots, and should have little fear of material failures which would make flying close to the ground desirable in the event there is a need for a rapid descent and landing. Helicopter can be autorotated to a safe landing in the case of an engine failure, much as the fixed-wing single-engine aircraft can be glided to safety if the sole power plant falls. There is a concern, however, that in preparing for such emergencies by practicing their procedures too much, the risk of actual emergencies could be induced. An analysis published by *Flight* magazine in 1975 pointed to the risk-reward rations of excessive autorotation training. Data from all branches of the U.S. military showed an equal loss ratio between helicopter crashes during autorotation training and the crashes that resulted from improper autorotational techniques when actual emergencies were in progress. For the Army and Navy, almost one helicopter was lost during autorotation training for each helicopter lost while performing an actual autorotation landing. The loss ratio for the Air Force was eight times better, not because Air Force had better pilots, but because Air Force helicopters flew at higher altitudes during their missions.

The author of the *Flight* article, George Saunders, described how it took five to eight seconds after engine failure for a pilot to react and to stabilize a helicopter in an autorotational descent. He presented graphs indicating that for every 1,000 feet of altitude, a pilot could select a circular area under the helicopter equal to about one statue mile in radius. If the pilot doubled his altitude, he would increase his potential landing area by eight times. Saunders also documented that stretching the glide should only be accomplished by changing airspeed and not by raising the collective.

Subsequently, Bill Gabella, a helicopter flight instructor, wrote a five-part article in *Flight Operations* magazine titled "Autorotation Pointers for Pilots." Both he and Saunders made a strong case for using cruising altitudes much higher than 500 feet AGL. This raises the question of how did helicopter pilots acquire this flying habit. The obvious answer must be "from their instructors." Perhaps it is time to take a hard look at how we are instructing people to fly helicopters in the 1990s.

How do we teach someone to fly a helicopter? According to a recent informal survey by this author, most of today's rotary-wing instructors teach others to fly using the same methods, examples and techniques that were used by their instructors. As is said in almost every text on educational techniques, the first training or impressions an instructor gives to his students are very long-lasting, and in some cases permanent. If something is learned in an incorrect manner, it is very difficult for another instructor to modify a previously developed habit.

CIERVA Emergency Autorotation Checklist

Collective full down

1. If you delay this action, the rotor rpm will decay very rapidly, about 10 percent per second.
2. If you do not put the collective full down, the rotor rpm will decay faster than normal. Are you or something preventing it from moving to the full down position?
3. If you raise the collective to stretch the glide, the rate of descent will increase rapidly and the touchdown will probably be a very hard one and will occur a shorter distance along the ground than it would if proper airspeed were maintained.
4. If the collective is lowered too rapidly, especially during training, you may cause an engine power problem and turn a practice event into a real emergency. Be prepared for this.

Into the wind

1. Even with light winds, it is always best to touch down into the wind or crosswind with the lowest possible ground speed.
2. Always fly high enough so you can turn as much as possible into the wind before the touchdown. Make the turn early if you can.

Engine status

1. Is the engine still running? If yes, try to add some power if it will help. If it is not running, you are probably too busy to try a restart from low altitude.
2. If this is a training exercise, is the engine still running properly? If not, this is now a real emergency. Always be ready for such an occurrence.

Rotor rpm

1. Is the rotor rpm below the low limit? If so, is the collective fully down or were you just slow in lowering it at the beginning?
2. Is the rpm a little high? Probably that is OK. Save the extra rpm for the touch-down.
3. Raising the collective always lowers the rpm. Wait as long as possible before you raise the collective, save some rpm for touchdown.

Velocity (Airspeed)

1. What is the nose attitude of your helicopter? The airspeed may not be reading correctly. Just fly the correct helicopter attitude.

2. Use velocity (airspeed), not collective, to adjust glide angle and ground path length.

Area to land on

1. What you see is what you get, don't change your mind at the last minute.
2. Try to touch down into the wind or at least crosswind, rather than downwind. Keep your ground speed low.
3. Hitting any obstacle under control is much better than losing control trying to avoid the obstacle. The helicopter is expendable.

A look at records of the first helicopter students during the early 1940s reveals that they averaged about four hours total of helicopter flight instruction prior to solo. Today, in spite of modern, easier-to-fly helicopters and 50 years to perfect training programs, most students receive about 15 hours of instruction in a helicopter prior to solo. Even with this amount of training, there is still concern about students' ability to cope with emergencies that might require autorotational landings during their early flights. This brings us to the important question, "What is a good way to teach autorotations?"

The ideal way to do this would be to teach the student certain aspects of maneuvers and let him or her practice them during dual flight periods until the student feels very comfortable doing the maneuvers within acceptable standards. This educational technique is known as taking the whole and breaking it into parts, teaching the parts, and then rejoining the parts into a new whole.

We can take the whole (autorotation) and break it into four parts, or maneuvers:

- Pilot reaction to sudden helicopter yaw caused by engine power loss. Maintain directional yaw/control using the pedals. Do not overreact. Do not move the cyclic.

- Rapid entry into full power-off descent. Make collective reduction with positive yaw control and good attitude/airspeed control.

- Entering into quick stops from both level flight and power-off descents. Use aft cyclic to slow the helicopter without climbing. Do not fly to a full stop, but transition into air taxi at 10- to 20-knots airspeed. Avoid adding too much collective during the leveling-off process.

- Learn how to make landings from engine failures during air taxi at 5- to 15-foot heights and 10- to 20-knot taxi airspeeds. Try to not use much collective; leave it where it was prior to the engine loss if possible.

If a pilot can do these four maneuvers comfortably, he is ready to attempt them in rapid sequence, one after the other. If the pilot successfully does so, he has rejoined the four parts into a new whole – the autorotation.

A final comment about teaching the autorotation maneuver involves a memorized emergency procedures checklist. Student pilots have long been taught to memorize certain abbreviated checklists in addition to using the printed ones in the aircraft. Many pilots automatically go through the pre-landing litany of GUMP, for Gas, Undercarriage, Mixture and Prop. These short generic drills also can be used on the spur of the moment during an emergency, and then followed by the manufacturer's checklist when time allows.

I have created my own emergency checklist for use during autorotations, with a memorization aid (see text box above) based on an acronym spelled like the name of a rotary-wing pioneer. (Juan de la Cierva was the name of the developer of the autogiro which, with unpowered main rotors, always flew in a state of autorotation. Pulled through the air by a standard aircraft engine and propeller, the autogiro was the forerunner of today's helicopter.) When I ask a student for the engine out at altitude procedure, I expect him to state as a response the acronym CIERVA. This reminds him to do the following: Collective down, Into the wind, Engine status, Rotor rpm, Velocity, and Area for landing.

About the Author

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Hynes is certified as a flight instructor by the U.S. Federal Aviation Administration (FAA) and is a designated pilot examiner for airplanes and helicopters, a ground instructor and an accident prevention counselor. He also is an authorized inspector, and an airframe and power plant mechanic. With more than 15,600 flying hours, Hynes has conducted more than 700 airman flight certification examinations, and has participated in more than 150 accident investigations.

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APPENDIX E.
FAA/INDUSTRY HELIPORT DESIGN CONSENSUS STATEMENT

This Appendix contains the FAA/Industry Heliport Design Consensus Statement. This is the 16th version of a document developed during the extended negotiations between the FAA and Industry. Negotiations continued for almost a year after this particular version of the Consensus Statement was written. In the interest of keeping this a relatively high-level document, a very large number of consensus items were not included in this statement. In addition, under pressure from the Air Ambulance Industry, the FAA backed off on its intentions to adopt two-slope approach/departure paths. The two-slope approach/departure paths had been agreed upon by Industry and had been included in several draft versions of the revised AC. However, the two-slope approach/departure paths were not included in the version released for public review and comment.

HELIPORT TECHNICAL ISSUES
March 11, 1999

CONSENSUS ISSUES

1. VFR Approach and Departure Surfaces - General.

The VFR approach and departure surfaces apply to ALL heliports (PPR, GA, hospital, transport).

2. VFR Approach and Departure Surfaces - Slopes(s).

The revised Heliport Design AC will recommend "two segment" VFR approach and departure surfaces as described below:

First segment	Length: 805 feet long Slope: 1:12.5 Inside edge: Surface starts 20 feet outside the FATO
Second segment: Length:	3180 feet Slope: 1:6.25

Existing hospital heliports and prior-permission-required (PPR) heliports can continue to operate with 1:8 approach/departure surfaces. New facilities should meet the two-slope approach/departure surface recommended above.

3. Curved VFR Approach and Departure Surfaces.

The revised draft AC150/5390-2B will state that approach/departure paths may curve to avoid objects and noise-sensitive areas.

4. Protection Zone – GA and Transport Heliports.

For a GA heliport, the revised Heliport Design AC will recommend a 280 foot Protection Zone beginning at the edge of the FATO.

For a Transport heliport, the revised Heliport Design AC will recommend a 400 foot Protection Zone beginning at the edge of the FATO.

5. Protection Zone – PPR VFR Heliports.

At PPR VFR heliports, the revised Heliport Design AC will not recommend Protection Zones at PPR facilities.

6. FATO Length – GA and Hospital VFR Heliports.

The minimum FATO length should be 1.5 x the overall length (OL) of the design helicopter (private, GA, and hospital heliports).

7. FATO Use.

The FATO must not be used for parking a helicopter while another helicopter is making an approach to or a departure from the same FATO. A separate parking area will be recommended.

8. FATO Width.

All VFR heliports except Transport: The minimum FATO width should be 1.5 x the overall length (OL) of the design helicopter.

VFR Transport Heliports: 2.0 x RD but not less than 100 feet.

9. **Safety Areas/TLOF Marking.**

a. If the edges of both the TLOF and the FATO are marked, the minimum width of the VFR Safety area should be as follows:

GA heliports: 1/3 RD but not less than 20 feet

PPR heliports: 1/3 RD but not less than 10 feet, if the TLOF is marked with the standard heliport marking symbo (the "H")

1/3 RD but not less than 20 feet, if the TLOF is NOT marked with the standard heliport marking symbol (the "H")

Hospital Heliports: 1/3 RD but not less than 10 feet

Transport heliports: not less than 30 feet

b. When only the FATO is marked (i.e., the TLOF is unmarked), the current safety area recommendations are inadequate because the pilots have no indication that there is any potential hazard in being outside the TLOF. Thus, if the edges of the TLOF are not marked, the minimum width of the VFR Safety area should be as follows:

All heliports except Transport: 1/2 of the overall length (OL) of the design helicopter but not less than 20 feet. This recommendation is applicable irrespective of whether the standard heliport marking symbol (the H) is used.

Transport heliports: Not applicable. At a transport heliport, it is recommended that both the FATO and TLOF edges should always be marked.

c. The minimum recommended width of the VFR safety area will be the same on all sides of the FATO.

10. **TLOF Size.**

For elevated helipads, the minimum TLOF dimension should be 1.0 RD.

For hospital heliports (ground and elevated), the minimum TLOF dimension should be 1.0 RD but not less than 40 feet.

For ground-level GA heliports, the minimum TLOF dimension should be 1.0 RD. (See also item 11 in this document.)

For transport heliports, the minimum TLOF dimension should be 1.0 RD but not less than 50 feet.

11. Paved Portion of the TLOF.

At PPR facilities, if only a portion of the TLOF is paved, the revised AC will recommend that minimum length and width of this paved portion be 2 times the maximum dimension of the undercarriage of the design helicopter.

12. Wind Sock.

A windsock is recommended at all heliports.

13. Taxiway Terminology.

The revised Heliport Design AC will retain the terms of AC150/5390-2A (ground taxiway and hover taxiway). The term "air taxiway" will be deleted.

The revised Heliport Design AC will continue to use the term "taxi route" to mean the total width of the area used for taxiing (taxiway plus the appropriate clearances on each side).

14. Taxiways – Elevated Edge Markers in Grassy Areas.

Elevated markers are sometimes obscured by tall grass where lawn maintenance has been less than meticulous. The revised AC will call attention to this problem and offer several options on how a heliport operator might choose to address this issue including, but not limited to, the following: careful lawn maintenance, use of a 12-inch diameter or larger concrete pad around the base of the elevated marker, use of a 12-inch diameter or larger aluminum disc around the base of the elevated marker.

15. Taxiways – Visible Centerline Markings.

On paved taxiways, the revised AC will recommend painted centerline markings. On unpaved taxiways, the revised AC will recommend flush centerline markings (and caution on the need for maintenance to avoid the potential hazard of hitting a centerline marker that is no longer flush with the taxiway surface). Where the visibility of the centerline marking can not be guaranteed at all times, such as when snow or dust are common and it is not practical to remove it, the AC will still recommend centerline marking. However, under such circumstances, it will be recommended that the minimum clearances be based on the use of "sideline markers only".

16. Taxiways – Placement of Elevated Markers.

The revised AC will recommend that the elevated side line markers be placed 1 RD but no more than 35 feet apart (as measured from one side of the taxiway to the other) equally spaced about the centerline.

17. Hover Taxiways, Elevated Sideline Markers.

Recommended taxiway clearances on each side will be as follows:

With Centerline Marking - Taxiway Clearances from the side line markers: One-third RD plus 10 feet

Without Centerline Marking - Taxiway Clearances from the side line markers: One-third RD plus 20 feet

18. Ground Taxiways. This ground taxiway may be part of a paved apron or it may be a narrow paved path. At non-transport facilities, the path may be either a paved path or a stabilized surface suitable for ground-taxi operations.

a. With centerline marking, a path of a width two times the width of the helicopter undercarriage, and sideline markings of the path, the revised Heliport Design AC will recommend a total taxi route width of 1 RD plus 20 feet equally spaced around the centerline.

b. With centerline marking and elevated sideline markings of the path, the revised Heliport Design AC will recommend a total taxi route width of 1 RD plus 30 feet equally spaced around the centerline. The sideline markers should be placed 1 RD, but not more than 35 feet apart (as measured from one side of the taxiway to the other), centered equally around the centerline.

c. With NO centerline marking and elevated sideline markings of the path, the recommended clearance on the outside of the sideline markers should be one-third RD plus 10 feet. The sideline markers should be placed 1 RD, but not more than 35 feet apart (as measured from one side of the taxiway to the other).

19. <u>Taxiway to Parking Position Transition Requirements</u>.

If the parking position has centerline marking and the taxiway does not, the AC will recommend that the parking position centerline be extended for a distance of one-half RD in the direction of the taxiway.

20. <u>"Standard" Parking Position Markings</u>.

The revised Heliport Design AC will recommend that marking of parking positions include the following:

a. a circle that is 1 RD of the largest helicopter that will park at that position
b. marking indicating the RD of the largest helicopter (not necessarily the "design" helicopter) that the position can accommodate (e.g., RD 37 FT)
c. different size parking areas for different size helicopters are acceptable
d. solid centerline marking
e. an extended centerline that the pilot can see when positioned in the center of the parking position (solid for a "taxi-through" parking position, dashed if the position will not accommodate taxi-through operations)
f. a solid line, perpendicular to the centerline, under the pilot's shoulders when the helicopter is correctly positioned in the parking position, that extends far enough from the centerline that the pilot can see it on both sides of the aircraft
g. a parking position number or letter (if there is more than one parking position)
h. tip clearance that is a function of how the aircraft will approach the parking position (hover taxi or ground taxi) and how the aircraft will depart the parking position (taxi through, 180-degree turn), see below for specific dimensions
i. passenger walkway
j. When appropriate for operational reasons, an OPTIONAL nose line or an OPTIONAL nose-wheel line may be used.

21. <u>"Taxi-Through" and "Back-Out" Parking Positions with "Standard" Parking Position Marking</u>.

a. Hover Taxi. (These parking position spacing requirements are appropriate for skid-equipped helicopters and for wheeled aircraft when they hover taxi.)

Minimum space between the 1 RD circles that define the parking positions: One-third RD clearance, but not less than 10 feet

b. Ground Taxi.

Minimum space between the 1 RD circles that define the parking positions: 10 feet

22. Parking Position Spacing Requirements for Skid-equipped Helicopters and Wheeled Aircraft that Taxi into Parking Positions with "Standard" Parking Position Marking and Make a 180-degree Turn before Exiting.

a. Hover Taxi. (These parking position spacing requirements are appropriate for skid-equipped helicopters and for wheeled aircraft when they hover taxi.)

Minimum distance between the circles defined by the tail rotors in Figure 3-15 of AC150/5390-2A: One-third RD but not less than 10 feet

b. Ground Taxi.

Minimum distance between the circles defined by the tail rotors in Figure 3-15 of AC150/5390-2A: 10 feet

23. Tip Clearance.

In the revised Heliport Design AC, the contents of subparagraph 20b (Clearances) will be deleted. The replacement material in the revised AC will be consistent with this consensus document.

24. Altitude Correction – FATO Length.

The error in the equations (paragraphs 15b and 30c2) will be corrected. Figures 2-2 and 3-3 will be consistent with the corrected equations except that the curves will be modified so that they are flat between sea level and 1000 feet MSL. The revised AC150/5390-2B will not recommend the use an altitude correction at PPR heliports.

25. Lateral Dimensions of VFR Approach/Departure Airspace.

In the draft Heliport Design AC, the FAA proposed a significant increase in the **lateral dimensions** of the minimum recommended VFR approach/departure airspace. Since we have not reached a consensus, discussions on this issue will be deferred to the development of a Heliport/Vertiport Design AC.

26. Dynamic Loading.

Both in the USA and in the international arena, there are debates underway about the interpretation and application of heliport dynamic loading requirements. In the USA, however, this issue is not yet ripe for a consensus decision. Thus, on this particular issue, the revised draft AC150/5390-2B will not differ significantly from AC150/5390-2A. Discussions on this issue will be deferred to the development of a Heliport/Vertiport Design AC.

27. Transport Heliport – FATO Surface Characteristics.

The revised AC150/5390-2B will state that the FATO may have a turf surface except for the TLOF for which a paved surface will continue to be recommended.

28. Marking and Lighting of Objects that are Difficult to See.

In all directions from a heliport, the revised AC150/5390-2B will recommend that wires and other objects that are difficult to see be marked and lit if they penetrate an 25:1 surface starting at the edge of the safety area and extending out 100 feet.

Under approach/departure paths and on both sides of such paths (within 100 to 200 feet), the revised AC150/5390-2B will recommend that wires and other objects that are difficult to see be marked and/or lit.

29. Wording Changes.

a. Application. In the "Application" paragraph of the preamble, the follow wording will be added:

To the extent that it is feasible and practical to do so, the standards in this AC should be used in planning and designing improvements to an existing facility when significant expansion or reconstruction is undertaken.

b. General. In the "General" paragraph of Chapter 2 (General Aviation Heliports), the follow wording will be added:

NOTE: To the extent that it is feasible and practical to do so, the standards and recommendations in this AC should be used in planning and designing improvements to an existing heliport when significant expansion or reconstruction is undertaken. Furthermore, existing PPR heliports may continue to follow the recommendations and standards applicable at the time of design.

c. General. In the "General" paragraph of Chapter 4 (Hospital Heliports), the follow wording will be added:

NOTE: To the extent that it is feasible and practical to do so, the standards and recommendations in this AC should be used in planning and designing improvements to an existing heliport when significant expansion or reconstruction is undertaken. However, existing hospital heliports may continue to follow the recommendations and standards applicable at the time of design.

d. Approach/Departure Surfaces. In the "Approach/Departure Surface" paragraph of Chapter 2 (General Aviation Heliports) and Chapter 4 (Hospital Heliports), the follow wording will be added:

NOTE: When the standard two-segment surface is incompatible with the airspace available at the heliport site, no operation may be conducted unless helicopter performance data supports a capability to safely operate using the actual approach/departure surfaces. This performance data would replace that indicated in figure 2-5 and the use of the site would be limited to those helicopters meeting or exceeding the required performance.

HELIPORT TECHNICAL ISSUES
February 4, 1999

BACKGROUND INFORMATION

In the final iterations of the list of Consensus Issues, both the FAA and Industry spokesmen sought to obtain a concise document that would speak to a very broad audience. In the interest of achieving this, a number of items were removed from what had been included, on a consensus basis, in earlier versions of this list. In addition, some of the remaining text was shortened. Should any questions or misunderstanding arise concerning these changes, this background document has been prepared to explain what has been removed from or shortened in the final version of the list of consensus issues and why this was done. Items removed fall into several categories:

a. Items on which there was no significant disagreement. These items had previously been included by way of assurance for those who were concerned about the possibility that some change was imminent. In the interest of being concise, they have been removed.

b. Redundancies. A number of items were removed or shortened because they were redundant. Previously, this redundancy had been included in the interest of clarity. As the parties involved have become more comfortable with the particular changes recommended, this redundancy has been deleted to make the consensus more concise.

c. Discussion deferred. A number of items were deleted from the consensus statement because they merely stated that a consensus had not been reached and that further discussions on proposed changes would be temporarily deferred. The FAA plans to continue address these items in the next development of a Heliport/Vertiport AC. Deletion of these items should NOT be viewed as FAA agreement that change is not appropriate.

d. Justification Statements. A number of items were shortened by the deletion of text justifying the particular change involved. This was done because the justification was not viewed as an essential part of the consensus statement.

[The numbering used in this Background Document is the same numbering as used in the December 10, 1998 version of the Consensus Issues.]

2. VFR Approach and Departure Surfaces - Slopes(s).

The revised Heliport Design AC will recommend a slightly modified version of one of several "two segment" VFR approach and departure surfaces in current Transport Canada Heliport Design regulations. A statement on the origin of this material was deleted from the consensus statement for two reasons. First, it is not essential that the origin of this material be addressed in the consensus statement. Second, while the FAA would prefer to adopt a modified version of second Canadian set of "two-slope" surfaces (in addition to the two-slope surface on which we have reached an agreement), Industry has opposed this proposal. Since addressing the origin of this material might open issues on which we have not agreed, this sentence has been deleted.

3. Curved VFR Approach and Departure Surfaces.

[In the interest of being concise, the following sentence has been deleted from this statement. This deletion should NOT be viewed as an FAA decision that change is not required on this issue.]

However, this issue will be reconsidered in a future revision in the interest of providing more definitive guidance on this topic.

5. Protection Zone – PPR VFR Heliports.

[In the interest of being concise, the following statement has been shortened. However, there is no disagreement on the contents of this statement.]

At PPR VFR heliports, if the heliport owner and operator ensure that all pilots are intimately familiar with the heliport (including such features as approach/departure path characteristics, obstacles in the area, etc.), the revised Heliport Design AC will not recommend Protection Zones.

6. **FATO Length – GA and Hospital VFR Heliports.**

[While the contingency has been removed from this statement in the consensus document, it is still understood and accepted by both FAA and Industry.]

Contingent upon continued agreement on the Approach and Departure Slopes of item 2 above, the minimum FATO length should be 1.5 x the overall length (OL) of the design helicopter (private, GA, and hospital heliports).

8. **FATO Width.**

[The following sentence has been deleted from this statement. This deletion should NOT be viewed as an FAA decision that change is not required on this issue. The FAA plans to pursue this issue in the development of a Heliport/Vertiport Design AC.]

(For IFR heliports, this topic will be reexamined for a future revision of the AC.)

13. **Taxiway Terminology.**

[In the interest of being concise, the following was deleted from the first part of this statement. However, there is no disagreement on these points.]

The term "air taxiway" will be deleted since neither FAA nor Industry has been able to identify anyplace in the USA where such a taxiway is in use.

Note: Industry has argued persuasively that the terms "ground taxiway" and "hover taxiway" are more descriptive of these operations than the ICAO terms and that the US terms are actually in wider use internationally than the ICAO terms. If a sufficient number of ICAO members are persuaded by this argument, perhaps ICAO will adopt these AC150/5390-2A terms during a future revision of ICAO documents. If not, the FAA may wish to reconsider this decision.

15. **Taxiways – Visible Centerline Markings.**

The following two sentences were deleted from this statement in the interest of being concise. In the present AC, elevated centerline markings are only recommended for air taxiways. Since neither FAA nor Industry has identified any air taxiways in use in the USA, they will not be mentioned in the next draft. There is no disagreement between the FAA and Industry on either of these statements.

Elevated centerline markers are NOT recommended because they present an obstruction hazard. Flush centerline markings disappear as soon as it snows.

16. Taxiways – Placement of Elevated Markers.

The following material was deleted from this statement in the interest of being concise. However, there is no disagreement between the FAA and Industry on either of these statements.

In the draft AC150/5390-2B, Figure 2-7 (top picture) is very similar to Figure 3-6 (top picture) of AC150/5390-2A. Both of these pictures show raised markers at the very outer limits of a taxi route. In the absence of other visual guidance (and appropriate pilot education), there is nothing that provides the pilot with a clear signal that the helicopter rotor blade tips should not protrude outside the raised markers. Such an operation would not provide the pilot with the expected tip clearance. Thus, the placement of these markers, as shown in these figures, is inappropriate.

17. Hover Taxiways, Elevated Sideline Markers.

[The following statement was deleted because it was redundant (see item 16).]

The revised AC will recommend that the elevated side line markers be placed 1 RD but no more than 35 feet apart (as measured from one side of the taxiway to the other).

18. Ground Taxiways, Paved section is only 2 times the Width of the Undercarriage (Surrounding Area is Unpaved, Marked/Painted Centerline Markings, Marked/Painted Edges.

[There were a number of redundancies in items 18 through 22. In the interest of being concise, these have been combined and consolidated.]

[The following statement was deleted from items 18 through 22 because there was no disagreement on this point.]

The minimum dimensions defined for a ground taxiway may NOT be adequate for use by skid-equipped helicopters or for hover-taxi use by wheeled aircraft.

19. Ground Taxiways Through a Paved Airport Apron, Marked/Painted Centerline Markings, Marked/Painted Edges.

20. Unpaved Ground Taxiways (taxiway surface is adequate for ground-taxi operations), Flush Centerline Markings, Flush Edge Markings.

21. Unpaved Ground Taxiways (taxiway surface is adequate for ground-taxi operations), Flush Centerline Markings, Elevated Sideline Markers.

22. Ground Taxiways (paved or unpaved), No Centerline Markings, Elevated Sideline Markers.

23. Taxiway Requirements for a Variety of Helicopters (Wheeled and Skid-equipped).

[This item has been removed from the consensus statement because there was no disagreement on this issue.]

The revised Heliport Design AC will continue to recommend that the more demanding requirement will determine what is required at a particular site. Usually, the taxiway requirements for skid-equipped helicopters will be the most demanding. However, when the largest helicopter is a very large, wheeled aircraft (e.g., the S-61), and the skid-equipped helicopters are all much smaller, the taxiway requirements for wheeled helicopters may be the most demanding.

24. Taxiway to Parking Position Transition Requirements.

[This item has been removed from the consensus statement because there was no disagreement on this issue.]

The revised Heliport Design AC will continue to recommend that taxiway centerline markings continue into parking positions.

26. Parking Position Spacing Requirements for Skid-equipped Helicopters and for Wheeled Aircraft that Hover Taxi into "Taxi-Through" Parking Positions with "Standard" Parking Position Marking.

In the interest of being concise, items 26 and 27 were consolidated into one item.

27. Parking Position Spacing Requirements for Wheeled Aircraft that Ground Taxi into "Taxi-Through" Parking Positions with "Standard" Parking Position Marking.

28. Parking Position Spacing Requirements for Skid-equipped Helicopters and Wheeled Aircraft that Hover Taxi into Parking Positions with "Standard" Parking Position Marking and Make a 180-degree Turn before Exiting.

In the interest of being concise, items 28 and 29 were consolidated into one item

29. Parking Position Spacing Requirements for Wheeled Aircraft that Ground Taxi into Parking Positions with "Standard" Parking Position Marking and Make a 180-degree Turn before Exiting.

30. Parking Area Width Requirements for a Variety of Helicopters (Wheeled and Skid-equipped).

[This item has been removed from the consensus statement because there was no disagreement on this issue.]

The revised Heliport Design AC will continue to recommend that the more demanding requirement will determine what is required at a particular site. Usually, the parking area width requirements for skid-equipped helicopters will be the most demanding. However, when the largest helicopter is a very large wheeled aircraft (e.g., the S-61), and all skid-equipped helicopter are much smaller, the parking area width requirement for wheeled helicopters may be the most demanding.

In the same vein, the revised Heliport Design AC will recommend that parking requirements should be based on how the aircraft will operate rather than on the undercarriage (wheeled versus skids). Consider, for example, parking on a pier where aircraft hover-taxi to the parking positions over water. Since ground taxiing is impossible, even a wheeled helicopter will hover-taxi into a parking position. Thus, the parking position should be designed as though the aircraft was skid-equipped [Note: This is consistent with the intent of the FAA/Industry WG that developed AC150/5390-2A.]

33. Standard Heliport Marking Symbol.

In a joint FAA/Industry/Military program conducted in the late 1960's, a wide variety of candidate heliport marking symbols were tested based on a pre-agreed list of six types of guidance (visual cueing) that were desired from this symbol. All parties in this test were motivated by a desire to increase the safety of heliport operations by providing better visual cueing. Test identified two symbols that provided this desired visual cueing. The FAA and Industry chose the first symbol, a Maltese Cross, as the standard heliport marking symbol in the late 1960's. In the late 1980's, the FAA and Industry chose the second choice, the "broken wheel", as the standard vertiport marking symbol.

In the late 1970's, however, the Maltese Cross was rejected after a charge was made that it was anti-Semitic. The "H" has been adopted as the standard heliport marking symbol. However, the Heliport Design AC specifically states that any company logo can be used instead at private heliports. While none of these company logos have been tested in a manner similar to the test program of the 1960's, many company logos are similar in design to symbols that were tested and rejected as providing inadequate visual cueing.

The FAA agrees with Industry that a company logo provides a unique safety benefit by identifying a heliport as a private facility. In an area where there are several heliports, a company logo can assist pilots by identifying the ownership of a specific heliport. However, the company logo does not necessarily provide all of the other safety benefits that the standard marking symbol provides.

Certain heliport operators are unwilling to agree to the recommendation of the standard heliport marking symbol at all heliports. **Industry has proposed that the company logo be allowed if the size of the safety area is increased. The FAA has accepted this compromise (see item 9).**

37. <u>Marking and Lighting of Objects that are Difficult to see and Avoid</u>.

In all directions from a heliport, the revised AC150/5390-2B will recommend that wires and other objects that are difficult to see be marked and lit if the penetrate an 25:1 surface starting at the edge of the safety area and extending out 100 feet. (The comparable surface in the current AC150/5390-2A is a 25:1 surface extending out to 500 feet from the edge of the FATO.)

Industry proposed the change from 500 feet to 100 feet. The FAA has accepted this change but recommends that it start at the edge of the safety area rather than the FATO edge.

The FAA proposed that the 25:1 surface be changed to an 8:1 surface. Industry proposed that any obstacle of any height be marked and lit. As a compromise, the FAA proposes to retain the 25:1 slope.

APPENDIX F. ACRONYMS

AC	advisory circular
A/C	aircraft
ADA	Americans with Disabilities Act of 1990
AEI	all engines inoperative
AFCS	automatic flight control system
AGARD	Advisory Group for Aerospace Research and Development
AGL	above ground level
AHS	American Helicopter Society
AIP	Airport Improvement Program
ATC	air traffic control
ATCT	air traffic control tower
AWOS	automated weather observing system
AZ	azimuth
BA609	a 9-passenger civil tiltrotor being built by Bell and Agusta
BB609	a 9-passenger civil tiltrotor that was being built by Bell and Boeing
BVI	blade-vortex interaction
CAT	category
CIERVA	Juan de la Cierva, developer of the autogiro
CTR	civil tiltrotor
CTR-7	the 7th tiltrotor experiment on the NASA VMS
CTR2000	a "notional" 40-passenger civil tiltrotor
CTRDAC	Civil Tiltrotor Development Advisory Committee
dB	decibel
DFAC	distance from the aircraft center
DH	decision height
DIAP	distance along the interaction plane
DNL	Day/Night Average Sound Level
DWP	decision waypoint
E-L	electroluminescent
EMS	emergency medical service
EPNL	Effective Perceived Noise Level
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FARA	final approach reference area
FATO	final approach and takeoff area
fpm	feet per minute
FTE	flight technical error
GA	General Aviation
GPI	glide path indicator
GPI	ground point of intercept
GPS	global positioning system
GVGI	generic visual glideslope indicator
H	identification symbol for marking the TLOF
HAI	Helicopter Association International
HALS	heliport approach lighting system
HF	high frequency
HIGE	hover in ground effect
HILS	heliport instrument lighting system
HLP	heliport layout plan
HNM	Heliport Noise Model
HOGE	hover out-of-ground effect

HRP	heliport reference point
HV	height-velocity
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
IGE	in ground effect
IMC	instrument meteorological conditions
ISTEA	Interstate Surface transportation Efficiency Act
km	kilometer
lbs	pounds
LDP	landing decision point
LED	light emitting diode
LO	liftoff
m	meter
MAP	missed approach point
MAWP	missed approach waypoint
MDA	minimum descent altitude
MOPS	minimum operational performance standard
MRI	magnetic resonance imager
MSL	mean sea level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NATO	North Atlantic Treaty Organization
NATOPS	NATO Operations Manual
NAVAID	navigational Aid
NEPA	National Environmental Policy Act of 1969
NFPA	National Fire Protection Association
nm	nautical mile
NPIAS	National Plan for an Integrated Airport System
NR	rotor speed (%)
NTIS	National Technical Information Service
NTSB	National Transportation Safety Board
OEI	one engine inoperative
OGE	out of ground effect
OIS	obstacle identification surface
OL	overall length of the design helicopter
PANYNJ	Port Authority of New York and New Jersey
PAPI	precision approach path indicator
Par.	paragraph
PCC	Portland Cement Concrete
PLV	powered-lift vehicle
PPR	prior permission required
RD	rotor diameter of the design helicopter
ROTWASH	rotorwash (a computer model)
SCAS	stability and control augmentation and control system
sm	statute mile
STOL	short takeoff and landing
R	rotor radius
RVR	runway visual range
RTOA	rejected takeoff area
SHP	shaft horsepower
TD	touch down
TERPS	terminal instrument procedures
TLOF	touchdown and lift-off area

TTY	teletypewriter
TW	taxiway
UC	maximum undercarriage dimension of the design helicopter
UNICOM	frequencies authorized for aeronautical advisory services to private aircraft
USA	United States of America
V-22	a military tiltrotor, approximately 30 passengers, built by Bell and Boeing
VASI	visual approach slope indicator
VFR	visual flight rules
VFTE	vertical flight technical error
VSDA	visual segment descent angle
VMC	visual meteorological conditions
VMS	vertical motion simulator
VSDA	visual segment descent angle
VSRL	visual segment reference line
VTOL	vertical takeoff and landing
WG	working group
XV-15	an small experiment tiltrotor, NASA/Army/Navy